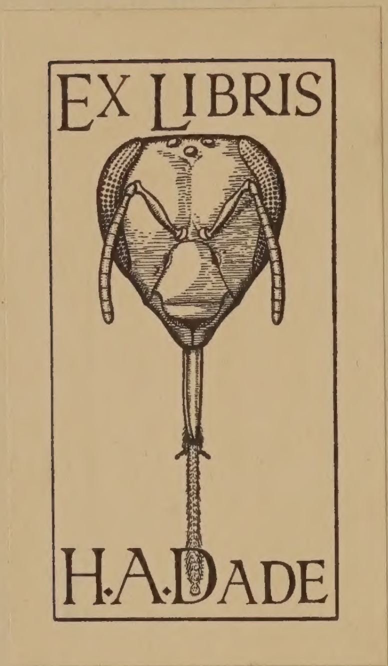
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BULLETIN No. 1.

Department of Agriculture,
Gold Coast.

Suggestions for the CONTROL OF TERMITES OR WHITE ANTS IN BUILDINGS

BY

W. H. PATTERSON, Government Entomologist.

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FOREWORD.

In May 1925, the Right Honourable the Secretary of State for the Colonies inquired whether the Government Entomologist could offer suggestions for the control of termites, and His Excellency the Governor called for a memorandum on the subject. The memorandum was completed in September and was found to be of such general interest that His Excellency authorized its publication.

Certain minor alterations and improvements have been effected in the original manuscript and the memorandum now appears as a Bulletin of the Department of Agriculture. The information it contains should prove valuable to all who are interested in the control of one of the most destructive insects of the Tropics.

The Department of Agriculture is indebted to Mrs. W. H Patterson for the line drawings used for illustrating this Bulletin.

G. G. AUCHINLECK,
Acting Director of Agriculture.

28th October, 1925.

SUGGESTIONS FOR THE CONTROL OF TERMITES OR WHITE ANTS IN BUILDINGS.

BEFORE consideration is given to measures to be tried in the Gold Coast for the control of Termites, (White Ants or wood ants) it would be well to review briefly the general economic position occupied by these insects and the various remedies which have been found more or less effective in other parts of the tropics.

2. Whilst it is difficult to get actual estimates of the amount of the damage done here, from figures furnished by Provincial Engineers it varies from 6% in the Central Province and 12% in the Western Province to 25% in Accra of the vote for the maintenance of existing buildings. No details are available for Ashanti. The actual damage may be more or less than this, for it is doubtful if white ant damage is kept distinct from general maintenance. No figures are available as to whether privately-erected buildings are more or less susceptible to such damage compared with buildings erected by the Public Works Department. Lefroy (24) says that it is not possible to estimate the amount of damage caused in India. Snyder (25)* in a Progress Report on "Tests of Methods of Protecting Woods Against Termites" estimates the annual amount of damage to forest products in the United States of America at forty-five million dollars, this being a conservative estimate based on 2% of the value of the yearly cut of forest.

3. A great deal more damage is done here in the Gold Coast than people are aware of, and there is some reason to think this is directly encouraged through a lack of appreciation of the working habits of the insects. Broadly speaking, most have an idea of the termites as a social community with kings, queens, soldiers and workers, but it is questionable if many realise that the large mound nests are, in most cases, the work of years. One nest in South Africa (18) is stated to be from 40–50 years old. This has an important bearing on the course of action to be taken when buildings are about to be erected on any given site and is discussed under. (§§–21 & 44.)

4. A nest of termites is the result of the union of a pair of the insects, which, of all the many thousands seen in the migratory swarm rising from the ground after rains, have been fortunate enough to escape their many enemies. Soon after reaching the ground the wings are cast and the female, attended by the male, seeks a safe spot under rubbish, dead wood or

*References to the bibliography on page 17 are given in brackets thus (1).

leaves, and makes a small hole. If conditions are favourable, a nest may be started in the ground or in the upper portion of a building. Only a small number of eggs is laid at this period. These start the establishment with workers and soldiers. Some six months are required for these to reach maturity, and during this time they are fed and cared for by the royal pair. Later on, as the community increases in size, all the work of foraging, building and scavenging is done by the soldiers and workers. In a colony it is possible to recognise five castes (8) or sections of individuals. These castes can be separated into (a) reproductive and (b) sterile forms of each sex. In addition to the king and queen the reproductive forms are divisible into (i) those with a hardened body-covering and fully developed wings; (ii) those with a slightly hardened body-covering and wings partly developed and (iii) wingless individuals. The sterile castes consisting of (iv) soldiers and (v) workers are either wingless males or females.

The queen of some termites slowly grows to an immense size and she is occupied solely in producing eggs. It has been estimated that as many as a million eggs may be produced in a year and that four thousand can be laid in a day.

5. This is of necessity only a brief outline, and when it is taken into account that there are some nine hundred species of termites in the tropics and subtropics, and that from the Gold Coast alone Prof. Silvestri found thirty species, it will readily be understood that a considerable range of variation must exist.* Broadly speaking, termites may be divided into two groups, those damaging crops and those causing injury to the wooden erections of man.

FOOD OF WHITE ANTS.

6. The food of termites is generally described as consisting chiefly of wood. According to Oshima (16) this can now be more clearly defined. Working in Formosa where most of the houses are built of wood, his experiments clearly show that the cellulose of the wood is the portion retained by the insects, lignin being excreted. When first formed in the plant, wood consists of cellulose. Later on this cellulose becomes "woody" the various tissues being lignified. Lignin appears to have a chemical composition nearly approaching that of cellulose: it is harder and more elastic than cellulose, it is readily permeable by water, but it is not absorbent.

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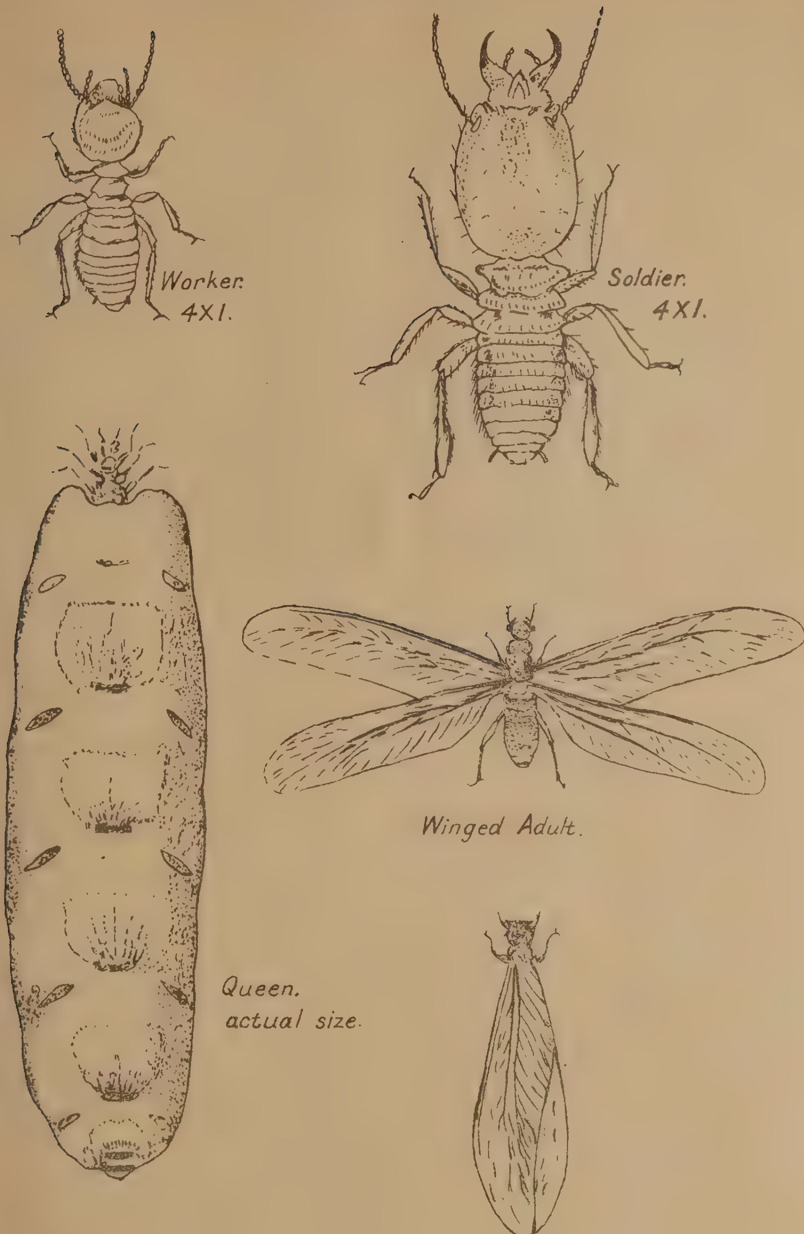
*Arboreal species of termites, which nest in trees and do not enter the soil, are reported to occur in India. It is obvious that if these types enter on the wing, ordinary methods of prevention would not be effective. Further information is being sought on this matter.

TERMES NATALENSIS.



Some stages of Termes Natalensis.

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7. With the knowledge that cellulose is the portion assimilated by the termites, it is easy to understand why these insects are so destructive to paper, books, cotton wool, and articles made from wood pulp, as these consist of practically pure cellulose. As cellulose alone is useless for building purposes, and as no attempts have yet been made to replace the cellulose with a substance which would permanently deter the termites from causing injury to the wood, all efforts have been directed along two lines, (a) to discover termite-proof timbers and (b) to find preservatives to render the wood immune from attack for as long a period as possible.

TESTING TIMBERS TO FIND RESISTANT BUILDING MATERIAL.

8. Much extremely valuable work has been done already in testing the relative immunity of various kinds of wood. Oshima (16) tested 45 woods in order to first prove whether the so-called immune timbers were really effective in preventing termite attack. He used the method of burying timber in land infested with the most destructive termite in Formosa, and though this method may leave room for error, and as pointed out by Dehra Dun in reviewing Kanehira's (6) results in " Indian Forester " XL. 1914, definite indications of absolutely immunity can only be obtained by actual infection with termites, his findings were that after twenty-one months in the soil only teak (*Tectona grandis*) and Cypress pine (*Callitris glauca*) were entirely immune. Kanehira, working in Formosa, tested 60 kinds of timbers and concluded that the characters which made timber termite-proof were

(i) the presence in the wood of some substance having a smell or taste unpalatable to the insects :

(ii) the presence of some poisonous substance :

(iii) the extreme hardness of the wood.

9. Chemical tests to ascertain the cause of the relative immunity of certain woods were started : after having shown that Snyder's assumption that the physical properties of woods were a factor of resistance was a fallacy, Oshima endeavoured to determine what were the actual chemical substances in certain woods which might assist in warding off termites. Using the same timber as in his former trials he found no special relationship existed between the resistance and the amount of ash and benzene extract, but as the percentages of benzene extract contained in teak and cypress pine were very high, these were further examined and determined to be sesquiterpenes.

HIGH COST OF IMMUNE TIMBER.

10. The use of the immune woods being prohibited by their high cost, search was then directed towards some product which would furnish sesquiterpene alcohol. Attention was given to camphor wood (*Cinnamomum camphora*) as the heavy oil of this is greenish and viscous, resembling that obtained from the cypress pine. One of the oils obtained, after the removal of the camphor crystals, was known as "camphor green" and this was shown by the chemist K. Kafuku to contain 10% of sesquiterpenes and 25% sesquiterpene alcohol.

11. Blocks of wood treated with various percentages of camphor green oil were tested and the results showed that the oil was an essential factor in preventing damage. Though the Formosa Government controls the production of camphor, it was considered the cost of the green oil alone would be too great, and ultimately it was used with a neutral oil of petroleum obtained from the crude oil of Niizu (Japan). This mixture cost about five cents per gallon (1919). It was of a pale yellow colour, did not stain timber, had a pleasant camphor odour, was non-poisonous to human beings, and was not volatile at ordinary temperatures.

12. At the present time, it is considered quite unlikely that camphor oil could be obtained at a reasonable rate for such work in West Africa, but for some years camphor trees have been grown in the Aburi Gardens and some have probably been distributed to other parts of the colony. The tree here does not readily produce seeds, but it could be increased by layering. It would make an excellent tall hedge or wind screen round cacao farms, and the camphor could be distilled at central factories from the prunings, which for this purpose might be dried and baled for easy transport. The financial aspect of this has not been considered. In this might be found the beginning of an additional export, whilst the protection from wind afforded by the hedges would probably diminish the severity, of attacks of thrips.

TIMBER PRESERVATIVES.

13. On testing the value of various other preservative Oshima obtained the following results :—

Preservative.	Chief Constituents.	Amount of damage.	Treatment used.	Length of Trial.
Atlas A. ..	Arsenic & sodium			
Wood Preservative A.	Tobacco, sodium salicylate & resin soap.			
Woodlin ..	Petroleum heavy oil and wood tar.			
Woodol ..	Wood tar ..		Coated three times	
Crepit ..	Creosote oil			
Wood Preservative B.	Tobacco and creosote ..			3 years
Carbolin ..	Anthracene oil .. 83%	0.0%		
Avenarius carbolineum ..	,, ,, 76%	33.3%		
Carbolineum Atlas	,, and heavy petroleum 62.5%	50.0%		
Stop-rot ..	Heavy oil from tar 50.5%	66.7%		

14. The results of Fletcher & Ghosh (19) in India showed the relative value of various preservatives to be : hot creosote effective for more than 81 months, cold creosote less than 28 months, Carbolineum 23, Powell process 21, lead arsenate 16, Mortant 15, Sideroleum 14, microleum 14, Solignum 12, zinc chloride 12, Timborite 11, lead chromate 7, Siderosthen 4 months.

15. In Rhodesia Jack (5) found that (i) arsenite of soda 10% solution, (ii) Atlas preservative used at full strength, (iii) Atlas preservative 10% solution, with one or two coats applied with a brush, rendered wood resistant for three years, whilst coal tar (one coat) Stockholm tar, creosote, Solignum, crude carbolic acid, and carbolineum did not protect for three years. Green (3) in Ceylon stated the protective effect of Solignum wore off after three years when exposed to weather. Fuller (1) in Natal advises the use of 10% arsenite of soda or creosote. A mixture of white arsenic, 4 ozs. dissolved in one gallon of boiled linseed oil, two coats being applied to the wood at intervals of one week, is said to prove useful in Rhodesia. Nemery (2) in the Belgian Congo says the odour of cresylatine appears to be exceedingly repugnant to termites when applied to the legs of bee-hives. Hill (17) in Australia recommends 1½ lbs. of white arsenic with 2 lbs. common washing soda to be boiled in one gallon of water and stirred when nearly boiling into 1½ gallons of hot coal-tar as a preservative for protecting posts.

METHODS OF APPLYING PRESERVATIVES.

16. The value of a preservative seems to depend not only on the variety of wood used and to preferential taste of the various species of termites locally present (8), but largely upon the method of the application of the preservative employed. In general work thorough treatment of wood with arsenicals is not easy without the use of pressure apparatus to ensure penetration of the wood. Soaking the wood for 2–3 days in the preservative is advised in Natal. Jack (5) considers the use of a brush to be better than simple dipping, but advises that the ends of the timber to be inserted in the ground should be soaked in the barrel containing the preservative and then coated with tar to prevent soil moisture from dissolving out the arsenite of soda. Snyder (25) says superficial brushing and dipping methods are only temporarily effective, much depending upon not only the character of the site, and geographical situation, but upon the chemical thoroughness of the treatment. Heavy or thick coatings of tar are valueless as preservative treatments. Several coats of coal tar creosote brushed on adds 2–5 years to the life of timber. If brushed on hot it was found to be more effective than was dipping in the hot preservative. After very comprehensive trials with open tank dipping and brush treatments involving the use of various types of coal tar creosotes, wood creosotes and carbolineum, he has decided that construction and other timbers to be in contact with the ground should be impregnated with coal tar creosote which he finds a permanent preventative against U.S.A. termites. The open tank process renders wood resistant to attack by wood-boring insects for at least 15 years. The full-cell pressure process is stated to render wood resistant for at least 25 years.

17. Coal tar creosote has been objected to as it discolours and has a strong odour, whilst wood treated with it cannot be painted afterwards. Snyder finds that pigment, notably green, can be added to the creosote and does not affect the resistant qualities of the wood. He recommends the addition of 1lb. of pigment to 1 gallon of creosote. When dipping was used coal tar creosote and pigment alone were employed, but when brush treatment was utilised the mixture was slightly thinned with linseed oil. The U.S.A. Forest Products Laboratory finds that red and brown pigments are less expensive than green, and that a smaller quantity is necessary to obtain a satisfactorily coloured creosote than is the case with green. The proportions advised are 8–12 ozs. of pigment (ground in oil) mixed with an equal bulk of linseed oil for each gallon of creosote. Red and brown pigments can be used by the open tank or pressure method, but the green can only be used with brushing or dipping.

18. The use of creosote in the Gold Coast is only feasible on exposed timber or in rough buildings, on account of its objectionable nature, but it is used wherever possible and consideration is being given to the advisability of erecting a creosoting plant.

19. It is not clear whether creosote as such is meant in §18, as men are frequently found speaking of Solignum as identical with creosote and Solignum is imported for use in place of creosote. Solignum is undoubtedly a useful general preservative for timber, but various trials show that it is not sufficiently lasting against termites, and in view of the results given in §14 the continued importation of Solignum in place of creosote is to be deprecated.

20. The condition of the wood as regards the moisture content (13) also has an important bearing, and only thoroughly seasoned material should be employed. When it is remembered that termites are unable to work without access to moisture, it will be seen how necessary it is not to insert unprotected timber into a thin layer of concrete.

DESTROY TERMITES BEFORE STARTING TO BUILD HOUSES.

21. Whilst the total eradication of termites (17) seems to be impracticable, even without new organisation much of the loss now due to them might be prevented, and if this view is accepted, then treatment of the building area is most important, and in infected areas this should receive attention before any constructional work is attempted. The area should first be thoroughly cleared of all bush and tall grass in order to locate the position of all termite nests. It is not sufficient to clear only enough land to enable building operations to be carried on; if this is done one or more nests may be overlooked and be the cause of future trouble.

22. In clearing the site, all stumps and large roots should be dug out, preferably removed by a stump extractor, and burnt, for as demonstrated by Richards (12) in the Federated Malay States whilst fumigation is the best palliative, the removal of stumps can be so effective that in cases where previously there was a mortality of 75% of 18 months old rubber trees, after clean clearing the termites had been completely eradicated. This applies with equal force to building-sites.

23. From information collected, it seems that in the Gold Coast, Africans do not seek to destroy the inmates of the termite nests, probably considering it impossible, but they simply level the mounds. As the mound-building habit appears to have originated in the necessity of disposing of the

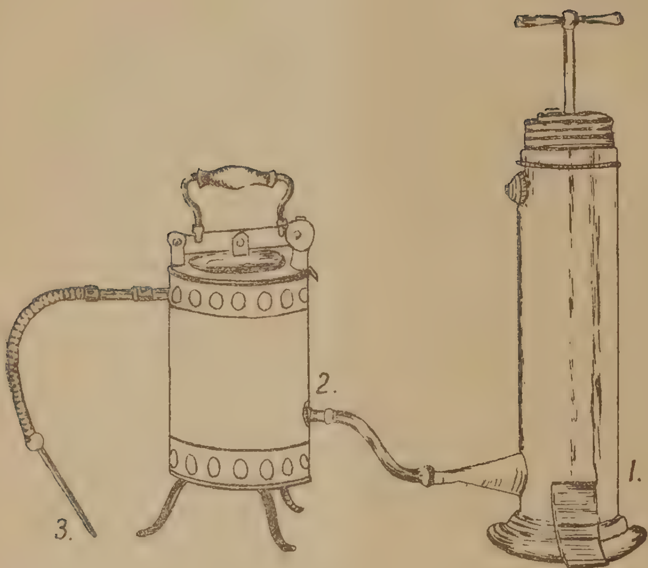
useless material excavated in forming subterranean chambers (26) there is little necessity for the renewal of the mound by the insects. Without the destruction of the inmates, much trouble may and does afterwards arise when buildings are erected on land even after levelling.

24. Measures to be used are (a) destruction of the queen and (b) fumigation. In order to destroy the queen, the nest must be broken into and a search made for the royal cell. Unfortunately when this method is employed in conjunction with levelling, a good deal of harm undoubtedly arises as the fact is overlooked that more than one queen may exist in the nest, and that colonies have the power to rear subsidiary (23) queens. Colonies arising in this way increase in size very rapidly, owing to the numerous queens, and this explains why so much trouble is often experienced on newly acquired building areas. Unless the contents of the nest are thoroughly broken up and thinly scattered on the surface of the soil, and it has to be borne in the mind this involves a good deal of work, for the nest may be several feet below the surface, practically the colonies are multiplied instead of being reduced. It would be advisable to sprinkle the ground with calcium cyanide, paradichlorbenzene, creosote, kerosene, etc., or place a few fowls on the site to destroy the balance of the termites. Kainit (4) might also be tried as it is said to be effective in driving termites from the roots of trees.

25. Soft wood stakes driven in to the ground at distances of about 25 feet apart and examined at intervals of 14–28 days would assist to locate hidden nests and determine where fumigation should be done.

HOW TO DESTROY TERMITE NESTS.

26. Destruction of the nest can be effected by fumigation. Green (3) attempted to destroy nests by exploding carbon bisulphide in the interior, but this method proved an absolute failure. Some years ago a simple machine was designed and used extensively in South Africa to drive into the nests triarsenious gas, formed by burning a mixture of sulphur and white arsenic in a closed vessel. This machine was so effective that in the Federated Malay States, where a termite (*Termes gestroi*) was exceedingly destructive on rubber estates, Pratt (27) in 1910, recommended that each estate should include two of these machines in the tool stock.



MACHINE FOR FUMIGATING WHITE ANTS.

1. Pump to drive air into 2.

2. Furnace to burn arsenic and sulphur.

3. Nozzle to be inserted into nest.

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27. The machine consists of a small furnace, to which is attached an air pump ; from the furnace a tube conveys the gas in to the nest. To operate the machine, a small quantity of red hot charcoal is placed on the grating in the furnace, and on this is scattered a tablespoonful of the mixture consisting of 87.5% by weight of arsenious oxide and 12.5% flowers of sulphur ; the lid of the furnace is rapidly clamped down by means of an attached iron peg and air quickly pumped through and continued for 5–15 minutes. In the meantime the delivery tube or nozzle has been inserted into a live portion of the nest. With large nests it is advisable to inject the gas from several points. Whilst the operation is being performed gas will be found issuing from holes scattered over the area, often several hundred feet from the main nest. These have to be promptly closed by stamping down the soil, or by covering with damp clay or swish (puddled clay.) In fact it is a good plan to have a preliminary trial, taking a handful of any damp material capable of making a considerable quantity of smoke before the poison mixture is used, so as to close as many of these openings as possible. The poisonous fumes kill a large number of inhabitants, and as some of the termites consume the dead bodies the deadly work of the arsenic is passed on. For this reason it is advisable to leave the nest closed for at least seven days after fumigation.

28. Indifferent success with this fumigator is likely to occur through (i) badly kept apparatus, (ii) faults in the proportions of the mixture, and (iii), insufficient heat to volatilise the arsenic.

OTHER POSSIBLE AIDS.

29. The possible use of other chemicals for killing termites is being considered. Feytaud (17) has experimented with chloropicrin (tear gas) with successful results, and there is some reason for thinking this material may be used in ridding houses of these pests. It is already being used for seed fumigation.

30. Paradichlorbenzene (3) under some conditions might prove an excellent soil fumigant, as the colourless crystals are readily volatile, and the vapour, whilst harmless to human beings, is poisonous to insects. It is comparatively cheap and is non-inflammable, and has given good results against boring insects. As yet it does not seem to have been tried on termites. The crystals, being easily handled, might be used in the runways on and in buildings, but in many cases its action in the nests would probably be too slow.

TREATMENT TO PREVENT TERMITES FROM ATTACKING BUILDINGS.

31. Measures to deter termites from attacking buildings, other than the destruction of their nests and the employment of wood made distasteful to them, are :—

(a) erecting the buildings on piers
(b) the employment of a metal termite-proof course
(c) termite-proof buildings.

32. The first is of value as it admits light and air into the space between the soil and the floor. Though termites can work exposed on the surface in a very humid place, as a general rule they prefer to work under a cover, which has the advantage of protecting them from enemies. The space readily permits a constant watch to be kept for signs of runways on the base of the piers. Fuller (1) in Natal advises that the piers should be hollow and have openings to admit light and air, and that if constructed of brick or stone these should be set in sand and concrete.

33. Oshima, (16) commenting on records of termites attacking brick buildings in Formosa, states that it is absolutely impossible for the brick itself to be attacked, but the spaces left between the bricks and mortar are used as runways. Cement mortar and lime mortar were used in construction, the latter almost exclusively until a recent date. The soldier of *Coptotermes formosanus* secretes a milky, acidulous fluid which acts upon the lime and the insects are enabled to work their way between the bricks. As soon as the Government demanded the use of cement mortar reports ceased to be made of damage to brick walls.

34. Statements are frequently made in the Gold Coast by those engaged in building that termites eat their way through concrete, and the Public Works Department in correspondence states that on several occasions bungalows erected on piers have been discovered to be in a shocking condition of infestation.

35. The reasons for this are (a) using land before it is cleared of termites (b) the use of too porous concrete with insufficient mixing (c) inserting posts in a thin layer of wet concrete with little or no protection to the bottoms of the posts.

36. Naturally when nests have been disturbed, and not destroyed with their contents in the course of building operations, it is to be expected the termites will do their utmost to penetrate any superimposed layer, more particularly so if it contains any inviting food such as pine-wood posts, or pieces of casings or forms. Not only does Oshima (16) destroy the

nests before the erection of termite-proof buildings, but he also considers it necessary to keep the site free from future infection. For this purpose the surface of the ground is sprinkled with a heavy oil of petroleum, creosote oil, or a mixture of heavy oil of petroleum and cresol, called "Termitol" at the rate of one gallon to six square feet of ground.

Being non-volatile at ordinary temperature, and insoluble in water they are said to be effective for a long time as they remain in the ground unchanged.

AVOID JOINS AND CRACKS IN THE CONCRETE.

37. Termite-proof concrete layer. To effect this, one layer of cement concrete is spread over the whole area, the edges extending three feet beyond the external walls of the building. This is done as soon as the footings are completed. The whole surface is then covered with cement mortar and allowed to set. Great care has to be taken that the entire layer is spread at the same time, as it has been repeatedly shown that when the work is undertaken in sections, joins are formed which can rarely be made tight enough to prevent the intrusion of termites.

38. It is stated to be "practically impossible to lay a termite-proof bed of concrete under a building in the Gold Coast owing to cracks caused by subsidence and contraction."

39. It should be noted that the writer says "under a building," that is, presumably one already in existence. This is contrary to Oshima's idea. Concreting beneath a building after its erection, with possibly wooden staircases directly connected with the soil and with afterthought additions, is too frequently the cause of pier-erected bungalows being attacked from the ground. Assuming efforts have been made to follow Oshima's plan and failed, it has been suggested that probably subsidence cracks in the concrete layer and in the walls may be due to too shallow foundations, but this is a matter to be settled by building engineers.

40. Termite-proof courses formed by having zinc projecting on all sides of the pier is advised by some. This seems to have originated in Rhodesia (5) where it was recommended that after destroying the nests by fumigation, all brick buildings should have strips of zinc laid on the first course of bricks over the whole foundations, and projecting at least one inch on each side of the wall. A refinement of this method used in Calcutta is the insertion of two metal sheets, one of zinc the other of copper, in contact; the resultant electric current is reported to be effective in preventing the passage of termites.

41. In view of the local claim that the insects penetrate through concrete even this would be of no real value, unless the metal be made to entirely cover the course. Snyder and Zetek (28) have shown that one species can penetrate lead sheeting.

42. Always bearing in mind the possibility of differences between the penetrative ability of the large number of species concerned, Snyder and Zetek (28), dealing with *Leucotermes tenuis* found in one tunnel in the Canal Zone (Panama) 70 feet below the surface, state : —

> "Along the concrete walls where the galleries (runways) were scraped off, small holes made by these termites right into the concrete were found in places. These holes were usually at an angle of about 45° to the surface, and in one case almost one millimeter in depth, although the majority were only about one half millimeter deep. In all probability these intrusions into the concrete were made only in soft places."

WHAT SHOULD BE DONE IN THE GOLD COAST.

43. Measures to be employed for dealing with termites. There is unfortunately a local tendency to consider it necessary to start entirely anew, ignoring the experience of workers in other parts of the tropics, instead of benefiting by their work, using this as the basis of new operations. Based upon previous work, in future erections the following should be adopted :—

(1) Thorough clearance of the complete building area, removing all stumps and large roots ;

(2) destruction of all termite nests with fumigation by means of "Universal" White Ant Exterminator, using the sulphur arsenic mixture, or if the use of arsenic is objected to, possibly asphyxiation only could be depended upon, using sulphur and a Clayton fumigator for the purpose. Local or African Officers should receive a short course of training in this work. They should be of a similar grade to the Sanitary Inspectors, and for an area like Accra it might be found advisable to establish an organisation sufficient to (a) deal with infected areas and (b) to clear all termites within a radius of half a mile or so of the town. Extermination, not control, should be the aim.

(3) The employment of a concrete termite-proof course over the site of the building after the footings and base of piers have been started before the further progress of the work.

(4) Where possible, light and air should be allowed free admission beneath all buildings not built upon a termite-proof bed of concrete.

(5) Posts not to be inserted in concrete in or near ground level.

(6) Where iron uprights cannot be used in place of posts, these should rest upon iron shoes or stringers.

(7) Wood near the ground level should, as far as possible, be of **thoroughly seasoned** odum.*

(8) All exposed wood should be treated with coloured creosote, not Solignum.

HOW TO DRIVE TERMITES FROM BUILDINGS.

44. Whilst Zetek (20) is true when he says prevention is preferable to remedial measures, yet these must be adopted when buildings have been (i) attacked from nests at ground level or (ii) when established in the building as the result of the pairing of mature insects after flight. It is an acknowledged fact that the control of termites already in the wood of a building is an extremely difficult matter and some regard it as almost hopeless, particularly in the case of old buildings constructed chiefly of wood. This points to the necessity of careful work and the measures employed must be thoroughly and persistently carried on.

Measures to be used are :—

(1) If possible trace insects from outside of building.

(2) Search the surroundings of the building for nests or signs of presence of termites.

(3) †Fumigation from the nest if found, or from runways, as these, if followed up, will gradually indicate the centre of activity.

(4) All replaced wood to be impregnated with creosote or treated with arsenite of soda solution (see §15) and then brushed with creosote.

(5) Insertion of soft wood stakes in surrounding ground see (§25).

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* N.B. Odum is the local name of the wood of *Chlorophora excelsa*.

† *Note*.—It is feared too much may be expected from these fumigating machines. When the larger runways are found or the actual nest is located it is certain they may be depended upon to destroy the inmates. The great difficulty is that when only small runways are found, it is not easy to make the end of the nozzle of the machine sufficiently small to be admitted into the runways.

(6) The occupants of any bungalow or building should be required to report the presence of any signs of termite attack. They should also report the presence of any termite nests in the vicinity. (N.B.—The early replacement of posts now in or near to the ground is advised, as it is useless to expect occupants to continue to take a keen interest in this question of termite control if this is not done.)

FUTURE TRIALS BY THE ENTOMOLOGICAL SECTION.

45. Experimental work being undertaken as opportunity permits consists of :—

(1) Testing the value of "Universal" Exterminator in comparison with the Clayton fumigator which uses sulphur only.

(2) Fumigation with chloropicrin gas.

(3) Fumigation by "termitecid" cartridges recommended by Dietz & Snyder in "Biological Notes on the Termites of the Canal Zone and Adjoining Parts of the Republic of Panama, 1923."
These are said to generate volatile arsenical combinations which enter the galleries of the nests under great pressure.

(4) The use of sawdust baits mixed with arsenicals in attacked buildings.

(5) Tests of arsenic trichloride with kerosene in comparison with creosote for wood preservation.

(6) The possible value of *Coccobacillus acridiorum* and various fungi in controlling termites.

(7) Testing the relative value of native woods stated to be immune.

In view of what has already been done elsewhere with teak and other woods no useful results are anticipated from this. In addition to odum only Agu (Kobinino, Mahubi, Ashanti names for *Borassus flabellifer*) and Potrodum, Kwatandro, (Ashanti names for *Erythrophloeum micranthum*) are claimed to be immune. The first would be useless for general purposes owing to the difficulties of working it, whilst the latter, though it would probably be extremely useful for sleepers, and bridge work, might be too heavy for general building construction. The use of local timbers for some time must largely be governed by the cost of extraction and transport, and the present system of using imported timbers when treated as recommended may be shown to be justified.

W. H. PATTERSON,
Government Entomologist.

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Note.—Those wishing for a general work on this interesting group of insects should consult " Les Termites " by E. Hegh, 1922. This work is profusely illustrated ; has a large bibliography and can be obtained from Dulau and Companv. Price 45s.

FOREWORD.

This bulletin deals with the distribution of rainfall in the Colony of the Gold Coast, Ashanti and the Northern Territories.

The North coast of the Bight of Benin is on the whole low-lying and is remarkable for the absence of any striking head-lands or mountain-ranges close to the sea.

The cause of the relatively great differences in the annual rainfall in so short a distance as the 300 miles of the Gold Coast is a matter of considerable interest. Mr. Auchinleck explains how the zonal distribution of rainfall due, to the configuration of the land some distance inland from the Coast, is responsible for these variations.

C. H. KNOWLES,

Director of Agriculture.

Accra,

8th January, 1926

RAINFALL OF THE GOLD COAST.

(Summary of Figures to the end of 1924.)

THE available meteorological records are scant in view of the considerable area of the country. They consist principally of records of rainfall from 57 points of observation, for periods varying from 2 to 34 years between 1891 and 1924. Details concerning these stations are given in Table I. at the end of this paper, and it will be observed that they are distributed as follows :—

Gold Coast	Central Province	8	stations.
	Eastern ,,	18	,,
	Western ,,	11	,,
Ashanti		11	,,
Northern Territories		7	,,
Togoland		2	,,
		57	

The oldest of the stations is Aburi, which has been the headquarters of the Department of Agriculture since 1891, and where the meteorological records have been continued unbroken up to the present date.

Previous to 1924, ten of these fifty-seven stations ceased to take records and in 1925 two new ones (Achimota and Mpennasa) were opened, so that at present there are forty-nine observation points, or one for every 1,600 square miles of the country.

Twelve of the existing stations, (Aburi, Accra, Akuse, Asuansi, Axim, Ho, Kintampo, Keta, Kumasi, Sekondi, Tamale and Tarkwa) in addition to taking rainfall readings, are fitted with thermometers and the following observations are taken daily :

Maximum temperature in the shade
Minimum ,, ,, ,,
Maximum ,, ,, sun
Minimum ,, on grass (terrestrial)
Wet and Dry bulb readings.

From these readings calculations are made of the degree of humidity of the atmosphere, that is the percentage present of the maximum amount of moisture absorbable by the air at the time of observation.

In addition some of the stations record the "force of the wind" once a day, estimating it in accordance with the "Beaufort" arbitrary scale. Note is also taken of the percentage of sky obscured by clouds. These observations of wind and cloud appear to be of little value, and are not considered in this paper.

A serious defect is the absence of barometer and anemometer readings from the records. These instruments are not provided for any stations in the country, and are absolutely necessary if records of value and reliability concerning the various weather-changes are required.

MEAN MONTHLY DISTRIBUTION OF RAINFALL.

The mean monthly rainfalls for all stations for the years under consideration are given in Table II. at the end of this paper. The stations are listed in order of amount of rainfall, irrespective of their geographical situation. In 10 cases (Ada, Birimsu, Bunso, Cape Coast, Gambaga, Labolabo, Navrongo, Nkwatia, Obuasi and Winneba) records are given from stations closed previous to 1924: it is recognised that such records are not strictly comparable with the others, but in view of the paucity of records available, it has been thought advisable to include them.

The characteristic feature of the figures in Table I. is the close similarity shewn by all stations in the monthly fluctuations of their rainfalls. With the exception of the five most northerly stations (Gambaga, Navrongo, Tamale, Wa and Zuarungu) all shew two marked periods of drought, in August and in December and January. In the Gold Coast and Ashanti the year is split into two periods of rainfall, a major one in March to July and a minor one in September to November. In the case of the five northerly stations the mid-year drought is absent, and there is one unbroken rainy season from April to September: the northerly drought is prolonged from October to March.

These constant characteristics are seen clearly in the following Table A of mean monthly distribution of rainfall, in which the means are given for all stations grouped in accordance with the amount of their annual rainfall. The figures in Table A are shewn in graphic form in Diagram B opposite. For the sake of clearness of the diagram, the graphs for groups 70–60, 60–50 and 40–30 inches are omitted but they are closely parallel to the curve for group 80–70. The contrast between the distribution of rainfall in the northern stations and that occurring in the others shows clearly both in the table and in the diagram.

DIAGRAM 'B.'

Mean Monthly Distribution of Rainfall.

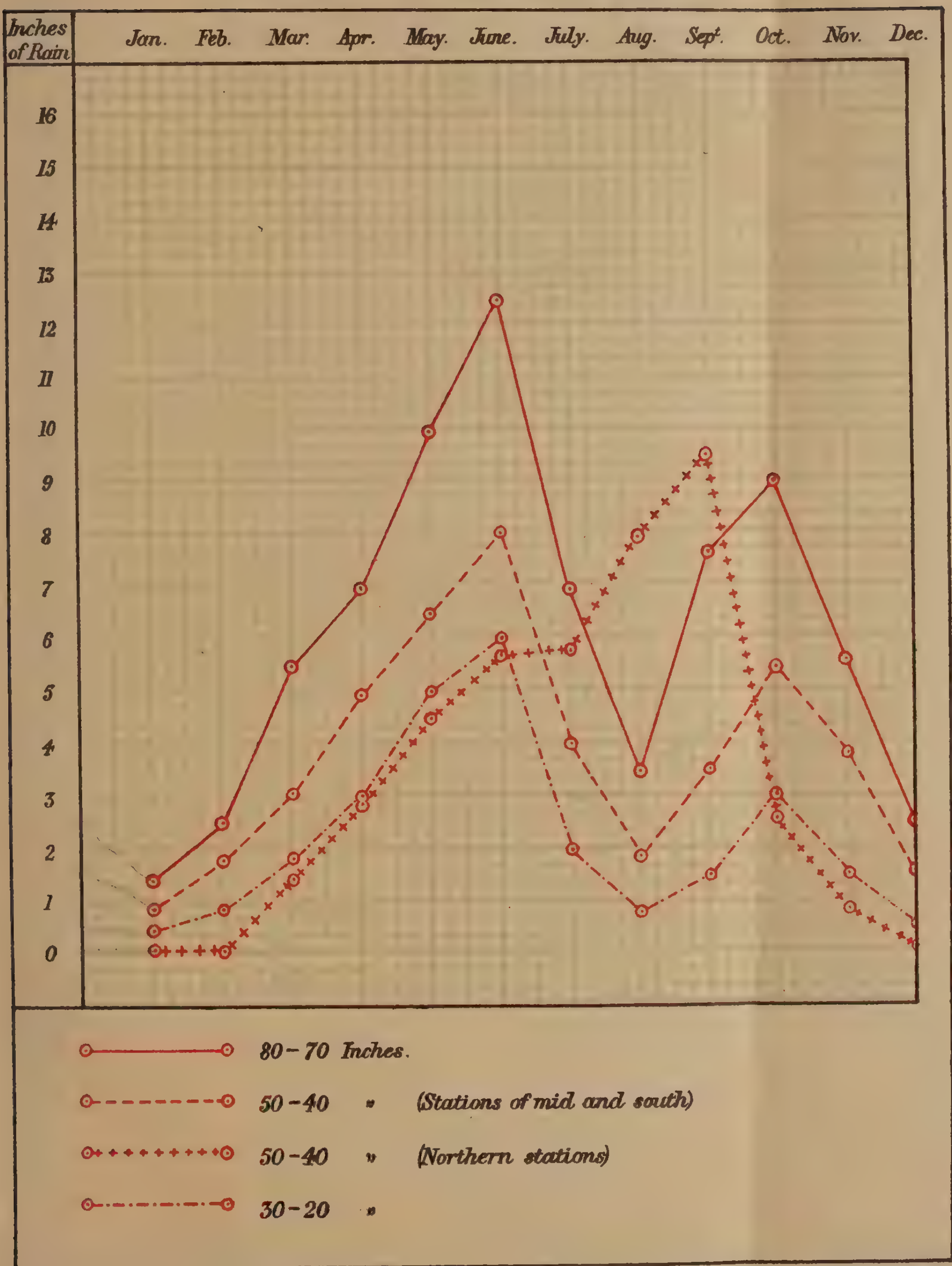

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TABLE A.

MEAN MONTHLY DISTRIBUTION OF RAINFALL.

(STATIONS CONSIDERED IN RAINFALL GROUPS.)

Groups.	No. of Stations considered.	Total No. of years considered.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total
80 to 70 inches	6	41	1.29	2.62	5.32	6.98	10.03	12.42	6.93	3.37	7.65	8.92	5.73	2.39	73.65
70,, 60 ,, ...	15	144	1.35	2.74	5.52	6.76	8.02	9.66	6.02	2.99	6.37	7.62	5.42	2.35	64.82
60,, 50 ,, ...	14	111	.86	2.31	4.63	5.99	6.43	7.99	4.68	2.81	6.85	6.83	3 68	1.45	54.51
50,, 40 ,, (mid and south) ..	10	184	.93	1.73	3.19	4.97	6.39	7.91	4.06	1 84	3.52	5.31	.72	1.64	45.21
50,, 40 ,, (northern)	5	40	.16	.21	1.60	3.18	4.58	5.78	5.78	8.92	9.53	2.36	.74	.25	43.09
40,, 30 ,, ...	3	20	.39	.45	2.43	3.33	7.06	8.32	2.59	.72	1.45	3.23	1.94	.86	32.77
30,, 20 ,, ...	4	37	.62	.78	1.73	3.02	5.12	5.99	2.11	.80	1.46	3.12	1.48	.55	26.79
			Northern Harmattan.		Major Rainy Season.				Mid-year Drought.		Minor Rainy Season.			Northern Harmattan.	

The percentages of the total annual rainfall which occur during the two rainy seasons are as follows :—

Group.	April–July.	April–Sept.	Sept.–Nov.
80–70 inches	56.6		30.2
70–60 ,, ...	55.5		29.9
60–50 ,, ...	54.5		31.8
50–40 ,, (mid and south)	58.6		27.7
50–40 ,, (northern)	—	87.6	—
40–30 ,, ...	72.1		20.2
30–20 ,, ...	67.1		22.6

ANNUAL VARIATIONS OF RAINFALL.

The mean annual rainfalls shewn in Table II. at the end of this paper are seen to range from 77.49 inches in the case of Adebrem to 25.52 in the case of Keta. In some cases the figures are the means of several years' records, and there are considerable fluctuations from year to year in the total annual rainfalls of every station for which adequate records exist.

In order to observe past annual variations and to estimate probable future ones, it is necessary to have records for a large number of years. In many cases the period of years over which records have been kept is hardly sufficient to afford a reliable indication of the probable future fluctuations. In the cases of 18 stations (Abompasu, Abra, Adebrem, Asamankese, Begoro, Butre (Seysie), Goaso, Half-Assini, Ho, Koforidua, Kpedshu, Labadi, Navrongo, Obuasi, Odumasi, Siwum, Wenchi and Yendi), rainfall records have been kept for only four years or less. The figures from these have therefore been discarded and the remaining ones used in calculating probable annual fluctuations, the results being given in following Table C :—

TABLE C.

Annual Fluctuations of Rainfall.

Station.	No. of years recorded	Mean Annual Rainfall Inches.	Range of Rainfall (Inches).			Average deviation from mean % mean. ±
			Highest Annual.	Lowest Annual.	Difference.	
Axim ..	10	76.49	109.65	47.64	62.01	23.6%
Kintampo ..	10	73.09	100.58	48.87	51.71	12.5 ,,
Birimsu ..	13	70.05	89.08	54.14	34.94	12.1 ,,
Mpraeso ..	7	69.31	85.26	57.55	27.71	12.8 ,,
Bunso ..	8	68.86	82.95	52.43	30.52	12.5 ,,
Tarkwa ..	21	68.86	95.03	48.22	46.81	12.9 ,,
Bekwai ..	11	67.06	104.90	53.64	51.26	15.7 ,,
Hemang ..	8	67.06	85.86	58.64	27.22	10.9 ,,
Anyinam ..	18	66.08	95.07	46.27	48.80	17.1 ,,
Nkwatia ..	10	65.00	81.80	46.54	35.26	11.9 ,,
Juaso ..	9	64.36	75.19	53.42	21.77	8.6 ,,
Kibi	12	63.86	79.90	45.77	34.13	13.9 ,,
Oda (Nsuaem)	10	61.58	83.75	43.61	40.14	17.9 ,,
Manso ..	11	61.18	83.70	54.46	29.24	10.1 ,,
Dunkwa ..	10	60.42	77.91	45.55	32.36	12.9 ,,
Kumasi ..	18	57.99	70.40	40.07	30.33	10.2 ,,
Ejura ..	9	57.71	80.75	47.45	33.30	16.5 ,,
Wiawso ..	9	55.20	70.44	40.14	30.30	16.9 ,,
Ayinasu ..	7	55.17	68.60	41.95	26.65	15.8 ,,
Sunyani ..	10	54.28	69.47	41.30	28.17	14.6 ,,
Peki Blengo	10	52.73	68.46	36.33	32.13	13.1 ,,
Asuansi ..	16	50.94	74.17	35.62	38.55	12.2 ,,
Labolabo ..	8	50.81	57.11	36.09	21.02	12.1 ,,
Salaga ..	10	50.05	64.52	37.79	26.73	17.6 ,,
Kete Krachi..	6	48.03	60.41	43.61	16.80	10.9 ,,
Aburi ..	34	47.52	73.16	32.09	41.07	15.3 ,,
Ajua ..	5	44.93	49.03	36.81	12.22	7.3 ,,
Wa	8	44.72	50.71	30.65	20.06	9.5 ,,
Zuarungu ..	7	44.52	51.62	37.93	13.69	18.7 ,,
Gambaga ..	8	43.71	45.96	37.67	8.29	13.0 ,,
Akuse ..	10	42.18	58.98	35.14	23.84	12.9 ,,
Tamale ..	15	41.84	61.77	32.36	29.41	16.2 ,,
Sekondi ..	11	40.53	57.76	33.80	23.96	12.6 ,,
Cape Coast ..	6	40.10	56.25	30.19	26.06	24.6 ,,
Saltpond ..	10	32.30	43.80	24.38	19.42	15.4 ,,
Ada	7	32.05	45.97	12.58	33.39	23.4 ,,
Accra ..	9	29.47	44.20	15.87	28.33	28.5 ,,
Winneba ..	7	27.91	44.27	14.60	29.67	26.5 ,,
Keta ..	19	25.05	51.44	13.88	37.56	32.7 ,,

The figures in this table are self-explanatory, excepting perhaps those in the last column. The 'average deviation' given there is calculated for a station by taking the difference between the mean rainfall for that station and each year's rainfall in turn: these differences are added together, plus and minus signs being ignored, and their sum divided by the number of years considered. This result is then calculated as a percentage of the mean rainfall.

The figure of average deviation from the mean may be used as follows: to take as examples Keta and Ajua, the stations with the highest and lowest deviations. In any one case, the rainfalls of these stations is, on the average, likely to be between the following limits.

Keta: between 25.05 + (32.7% of 25.05) and 25.05—(32.7% of 25.05)
i.e. „ 25.05 + 8.19 and 25.05—8.19
or 33.24 inches and 17.86 inches.
Ajua : between 44.93 + (7.3% of 44.93) and 44.93—(7.3% of 44.93)
i.e. „ 44.93 + 3.28 and 44.93—3.28
or „ 48.21 inches and 41.65 inches.

These average deviations may be summed up for the various groups of stations as follows:—

	Mean of average deviations.
Above 70 inches	16.0%
70 inches to 65 inches	13.4%
65 „ 60 „	12.7%
60 „ 55 „	14.8%
55 „ 50 „	13.9%
50 „ 45 „	13.1%
45 „ 40 „	13.1%
40 „ 35 „	—
35 „ 30 „	14.4%
30 „ 25 „	29.2%

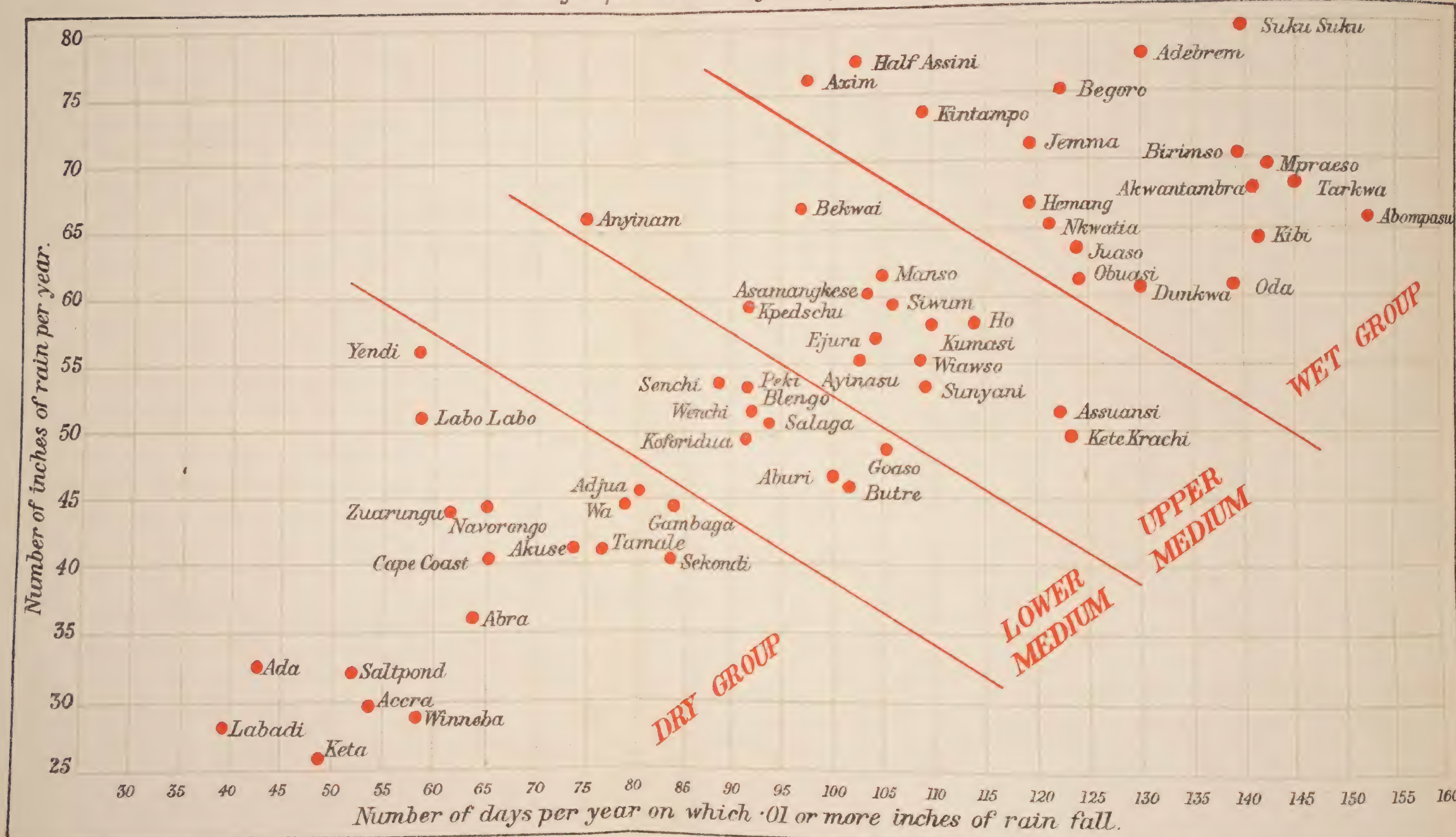
DEGREES OF WETNESS OF STATIONS.

T. F. Chipp, in his "Forest Officers, Handbook of the Gold Coast, Ashanti and the Northern Territories," adopts the device of mapping the various observation stations on a chart, the vertical axis of which represents inches of mean annual rainfall and the horizontal axis the number of "wet" days per year, a 'wet' day being one on which .01 inches or more of rain falls. The method is practically equivalent to multiplying the two figures together, and results in a tabulation of the stations in the order of their "wetness", that is a combination of their annual rainfall with the degree of uniformity with which it is spread over the year.

The tabulation which results is, of course, independent of the geographical positions of the stations, but by this table Chipp was able to obtain confirmative evidence of the occurrence of successive forest-zones which are common to the whole of West Africa. These zones are designated in order of their wetness, Guinea Zone (Evergreen Forest), Guinea Zone (Deciduous Forest), Sudanese Zone (Inland Savannah, Sudanese Zone (Coastal Savannah).

DIAGRAM 'D'.

Stations grouped according to degrees of wetness.



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The tabulation also indicated that certain stations, notably Kintampo and Ejura, which now lie in the Deciduous Forest and Inland Savannah, originally were well within the humid Evergreen Forest of the Guinea Zone. These results are obviously valuable from the point of view of the forester, as they indicate suitable areas for conservation and extension of forest. They bear also upon agricultural questions, since the optimum conditions for the cultivation of perennial crops such as cacao, kola, rubber and coffee are those occurring in the humid forest zones.

The method is employed in the present paper, the results being shewn in Diagram D opposite. In this chart Bunso and Odumasi do not appear, as the figures for 'wet' days are not available. The positions of Ada, Birimsu, Cape Coast, Gambaga, Labolabo, Navrongo, Nkwatia, Obuasi and Winneba, have been ascertained by using the rainfall averages from the present paper and the wet days from the "Forest Officers' Handbook". In addition the positions of Akwantambra, Jema, Senchi and Sukusuku, figures for which are not now available, have been borrowed from the older chart.

The stations appearing in the Dry Group in Diagram D all belong geographically to the Coastal and Inland Savannahs of the Sudanese Zone, in which both the amount and the distribution of the annual rainfall are defective. In the Upper and Lower Medium Groups, those stations occur in which either the amount or the distribution is unsatisfactory: these groups are of exceptional interest from an agricultural point of view, as they include many places at which cacao is the staple crop, for example Aburi, Anyinam, Asamankese, Asuansi, Koforidua, and Kumasi. In the Wet Group there appear centres at which cacao and rubber are grown and, stations from the wet south-western areas of the country which from a climatic point of view should be suitable for these perennial crops. The observation made by T. F. Chipp that Kintampo, which now falls geographically into the semi-dry zone, properly belongs to old areas of wet forest which have since disappeared is confirmed.

Until the rise of the industry in the Gold Coast, the cultivation of cacao had always been restricted to countries of plentiful and well-distributed rainfall. The plant was recognised to be one which requires the moisture and shelter of wet forest belts. In the Gold Coast the cultivation has been extended into areas partially and wholly unsuitable, and many of the earlier plantations have disappeared where conditions of drought were too severe. There remain many areas represented by the stations in the Upper and Lower Medium Groups in Diagram D, where the partial unsuitability of climate for this crop is obvious to the interested observer;

in these areas those pests such as Thrips (Heliothrips,) Helopeltis and Sankonuabe (Sahlbergella), which are recognised to be indicators of unsuitable climatic and soil conditions recur with exceptional severity.

ZONES OF RAINFALL.

From the figures in Table II. and the average deviations in Table C, a map has been prepared, shewing the zonal distribution of the rainfall of the country, and is reproduced at the end of this Bulletin. The contour-lines of rain fall in this map as far north as parallel 6°30′ are based on a fairly large number of records from a good many stations, and can probably be taken as practically correct for the periods under consideration. In the case of outlying areas in the west, north and east, records are scanty, and the contour-lines should not be accepted with certainty. As a whole, however, the arrangement of the zones of rainfall fits in with the general physiography of the country, and the system shewn on the map is probably correct in broad outline.

For ten months of the year the wind is constant from the south-west, while in December and January it blows from the north-east. These changes are probably due to causes similar to those giving rise to the north-east and south-west monsoons of India, namely the alternate heating and cooling of land areas, in summer and winter, while the adjacent sea remains at a comparatively constant temperature. The Sahara cools in winter to a lower temperature than that of the sea to the south, and the cooled, denser upper air falls to the surface of the land, driving outwards the lower warmer layers of air and so establishing a definite flow from north to south. In the summer the hotter Sahara air rises and its place is taken by relatively cooler air from the south. The winter depression of temperature in the Sahara is of much shorter duration and less intensity than that occurring in northern India and China, so that the north-east monsoon of the Gold Coast, or harmattan as it is called, lasts only two months.

The south-west winds passing over the sea are moisture-laden, and they deposit rain on the land, while the harmattan comes from dry land areas and brings with it to the Gold Coast the annual drought of December and January.

The first and most intense area of deposition of moisture is the crescent-shaped zone lying on the coast between Half-Assini and Axim, enclosed on the map by the 75 inches contour-line. From this area as a nucleus the deposition

continues as the wind progresses on its path to the north-east, in successive concentric zones of constantly diminishing intensity until the outlying zones of 45 inches and less are reached.

Here and there, as for example at Kintampo, Begoro, Ho and Tamale, the regularity of these zones is broken by small areas of greater or less deposition, these patches being due to the influence of local natural features of the land. There are indications that a wet area occurs in the east between Yendi and Ho, but owing to the lack of observation-stations in this area, this point is left in doubt. These local patches do not detract from the general correctness of the conclusion that the rainfall zones are concentric, and if records were available from countries to the east, north and west of the Gold Coast, it would probably be found that the outer zones (25, 35, 45 inches) sweep round the whole system and would prove to be continuous.

PHYSIOGRAPHY AND RAINFALL.

The rainfall of West Africa is controlled by a chain of highlands and mountains which runs roughly parallel to the coast from the neighbourhood of Cape Blanco on the west to Nigeria in the east. This chain is usually from 200 to 400 miles inland and the belt of coastal land lying between it and the sea falls naturally into a succession of parallel zones of rainfall. In general these zones are dry near the coast but become progressively wetter as the highlands are approached, and again drier after the prevailing south-west are increasingly depleted of their moisture. These zones are marked by characteristic types and arrangements of vegetation, varying with the rainfall, such as desert-scrub, open savannah, low forest, high forest and then back to desert conditions.

At certain points, one of which occurs in Sierra Leone, these highlands or their spurs approach the sea-coast and the coastal belt is reduced to a single zone of forest with a high rainfall. In the case of the Gold Coast, one of the zones the desert zone, is missing, and only savannah, forest and again savannah are present, the difference being apparently due to the fact that a spur of the main mountain chain approaches the coast and the deposition of rainfall begins somewhat nearer the sea than is usual. The rainfall system of the Gold Coast is therefore a local modification of the general system which occurs on the west coast of Africa.

The mountain-range of the Gold Coast runs from Kintampo south-west to Sunyani, and from there in a south-easterly direction between Kumasi and Ejura through Begoro and onwards down to Aburi. The system forms a wide semi-

circle with its concave face open towards the south-west, and acts as a bar to the southward march of the harmattan in December and January and to the northward path of the sea winds during the remainder of the year. As a result the effect of the harmattan is not serious in the areas lying south-west of the mountain-chain and the rain-bearing winds deposit most of their moisture before reaching the northern part of Ashanti and the Northern Territories.

It can hardly be due to chance that the successive concentric zones of rainfall are parallel to the mountain-range of the country. The wettest area, between Half-Assini and Axim lies practically at the focus of the concave south-western aspect of the range, and the system of contour-lines shewn on the map suggests that the degrees of intensity and the general shape of the rainfall zones are the outcome of the position and orientation of the range. It appears as though the winds travelling from south-west to north-east are slowed by the obstacle presented by the mountain-range and forced into a system of pressure-contours roughly parallel to the curve of the range.

The winds outside of this system and unobstructed by the mountains pass over the country without depositing their moisture. On the north-west and south-east faces of the system, in consequence, occur the contour-lines of lowest rainfall, those of 25 to 45 inches on the south-east coastal belt and of 45 to 55 inches on the north-west. Presumably these portions of the south-west winds deposit rain on some mountain mass far to the north and north-east of the Northern Territories, as part of the general system of West African rainfall.

G. G. AUCHINLECK,
Deputy Director of Agriculture.

TABLE I.

INDEX OF STATIONS OF OBSERVATION.

No.	Name of Station.	No. of years recorded.	Years of Records.	Observer.
			GOLD COAST.	
	Central Province.			
1	Abra	3	1922–1924	Department of Agriculture.
2	Asuansi ..	16	1909–1924	Department of Agriculture.
3	Ayinasu ..	7	1918–1924	
4	Cape Coast ..	6	1915–1920	Medical Department.
5	Hemang ..	8	1917–1924	Department of Agriculture.
6	Oda (Nsuaem)	10	1915–1924	Government School.
7	Saltpond ..	10	1915–1924	Medical Department.
8	Winneba ..	7	1015–1021	Medical Department.
	Eastern Province.			
9	Aburi	34	1891–1924	Department of Agriculture.
10	Accra	9	1916–1924	Medical Department.
11	Ada	7	1915–1921	Medical Department.
12	Akuse	10	1915–1924	Medical Department.
13	Anyinam ..	18	1907–1924	Scottish Mission.
14	Asamankese	2	1923 & 1924	Department of Agriculture.
15	Begoro ..	3	1922–1924	Scottish Mission.
16	Birimsu ..	13	1907–1919	West African Rubber Plantation.
17	Bunso ..	8	1906–1913	West African Rubber Plantation.
18	Keta	19	1906–1924	Medical Department.
19	Kibi	12	1913–1924	Department of Agriculture.
20	Koforidua ..	3	1922–1924	Department of Agriculture.
21	Labadi ..	2	1923 & 1924	Department of Agriculture.
22	Labolabo ..	8	1907–1914	British Cotton Growing Association.
23	Mpraeso ..	7	1915–19, 1923 & 1924	Medical Department.
24	Nkwatia ..	10	1910–1919	District Commissioner.
25	Odumasi ..	2	1922 & 1923	Department of Agriculture.
26	Peki Blengo ..	11	1914–1924	Department of Agriculture.

INDEX OF STATIONS OF OBSERVATION.

No.	Name of Station.	No. of years recorded.	Years of Records.	Observer.
	Western Province.			
27	Adebrem ..	2	1923 & 1924	Department of Agriculture.
28	Ajua	5	1920–1924	Palm Oil Estates Managers Ltd.
29	Axim	10	1915–1924	Medical Department.
30	Butre (Seysie)	4	1921–1924	Palm Oil Estates Managers Ltd.
31	Dunkwa ..	10	1915–1924	Offin Rubber Plantation.
32	Half-Assini ..	3	1922–1924	Customs Department.
33	Manso ..	11	1914–1924	Railway Department.
34	Sekondi ..	11	1914–1924	Medical Department.
35	Siwum ..	3	1922–1924	Customs Department.
36	Tarkwa ..	21	1904–1924	Department of Agricuture.
37	Wiawso	9	1916–1924	Department of Agriculture.
			ASHANTI	
38	Abompasu ..	3	1922–1924	Abompasu Cacao Estates Ltd.
39	Bekwai ..	11	1914–1924	Railway Department.
40	Ejura	9	1916–1924	District Commissioner.
41	Goaso	3	1922–1924	District Commissioner.
42	Juaso	9	1916–1924	Department of Agriculture.
43	Kintampo ..	10	1915–1924	Medical Department
44	Kete Krachi ..	6	1919–1924	District Commissioner.
45	Kumasi ..	18	1907–1924	Department of Agricul-
46	Obuasi.. ..	4	1915, 17, 19 & 1920	Medical Department.
47	Sunyani ..	10	1915–1924	Medical Department.
48	Wenchi ..	3	1922–1924	District Commissioner.
			NORTHERN TERRITORIES.	
49	Gambaga ..	8	1914–1921	Medical Department.
50	Navrongo ..	2	1915 & 1916	Medical Department.
51	Salaga ..	10	1915–1924	Medical Department.
52	Tamale ..	15	1910–1924	Medical Department.
53	Wa	8	1917–1924	Medical Department.
54	Yendi	3	1922–1924	Medical Department.
55	Zuarungu ..	7	1918–1924	Medical Department.
			TOGOLAND.	
56	Ho	3	1222–1924	Medical Department.
57	Kpedshu ..	2	1923 & 1924	Department of Agriculture.

TABLE II.

MEAN MONTHLY RAINFALLS FOR ALL STATIONS

Month.	Adebrem 2 years.	Half Assini. 3 years.	Axim 10 years.	Begoro 3 years.	Kintampo 10 years.	Birimsu 13 years.	Mpraeso 7 years.	Bunso 8 years.	Tarkwa 21 years.	Bekwai 11 years	Hemang 8 years.	Abompasu 3 years.	Anyinam 18 years.	Nkwatia 10 years.	Juaso 9 years.	Kibi 12 years.
January	1.62	1.42	1.51	2.88	.31	1.44	1.05	1.42	1.94	.97	1.02	1.21	1.24	.70	.84	1.19
February	2.99	4.26	1.86	4.96	1.92	2.77	2.50	2.55	3.42	3.24	3.67	1.80	2.73	2.32	2.13	3.05
March	3.83	8.57	4.41	6.09	4.81	5.71	4.60	4.33	6.02	5.34	6.65	5.06	6.48	4.60	6.26	5.78
April	10.58	6.45	4.93	14.50	6.89	6.46	6.04	5.54	7.37	8.16	6.74	7.09	6.10	6.29	6.56	7.09
May	10.94	9.60	14.77	8.17	8.56	7.92	8.18	8.11	8.86	9.22	8.46	7.79	8.22	7.60	7.73	6.32
June	17.95	18.70	15.25	8.71	11.12	9.79	10.05	9.87	10.52	10.27	7.70	9.54	9.73	9.60	9.48	9.37
July	7.44	3.59	9.21	2.15	6.88	7.03	7.94	8.83	5.87	5.73	5.38	6.21	7.49	6.49	5.56	4.77
August	1.58	.66	2.27	.95	4.69	4.68	4.21	4.96	2.10	2.77	3.22	1.01	3.78	4.11	2.31	3.04
September	4.51	2.71	3.12	8.66	13.40	8.11	8.97	8.42	4.38	5.84	5.10	15.01	7.52	9.02	8.37	5.81
October	7.89	9.46	7.53	13.19	9.82	8.36	7.79	9.34	8.33	8.72	8.92	1.86	7.85	8.52	8.58	8.33
November	6.49	6.26	8.27	3.86	4.2[illegible]	5.11	5.33	3.35	6.59	5.81	6.99	6.95	3.32	4.35	4.62	6.12
December	1.67	5.22	3.36	1.10	.43	3.07	2.05	2.14	3.40	1.49	3.22	2.81	1.62	1.40	1.92	2.99
Total	77.40	76.90	76.49	75.15	73.00	70.45	69.31	68.86	68.86	67.06	67.06	66.34	66.08	65.00	64.36	63.86

TABLE II.—(*contd.*)

MEAN MONTHLY RAINFALLS FOR ALL STATIONS.

Month.	Obuasi 4 years.	Oda (Nsuaem) 10 years.	Manso 11 years.	Asamankese 2 years.	Dunkwa 10 years.	Siwum 3 years.	Kpedshu 2 years.	Ho 3 years.	Kumasi 18 years.	Ejura 9 years.
Jan. ..	2.16	1.01	2.70	2.39	.84	.80	1.57	.64	.59	.64
Feb. ..	2.29	2.11	2.58	2.85	2.23	2.04	4.18	5.81	2.33	2.08
March	4.55	5.12	4.24	6.62	5.74	4.54	8.09	3.76	5.03	4.32
April ..	5.58	6.85	6.31	7.88	7.49	5.44	5.44	7.36	6.11	5.16
May ..	7.15	7.06	9.13	7.62	6.92	9.75	7.22	6.01	6.49	7.78
June ..	9.86	8.52	9.86	9.06	9.78	9.42	6.93	7.88	8.71	7.47
July ..	7.50	4.27	4.66	5.10	5.16	5.67	2.40	2.29	5.43	3.87
August	4.19	2.33	1.85	1.23	2.87	1.07	.61	1.51	3.11	2.62
Sept. ..	6.72	6.20	4.39	2.74	6.14	5.33	4.96	8.28	7.19	9.71
October	5.35	8.17	6.33	6.73	7.01	7.77	11.57	10.19	7.79	8.09
Nov.	5.75	7.52	5.61	6.20	4.78	5.51	3.75	3.11	3.93	4.61
Dec. ..	.93	2.40	3.52	2.07	1.46	2.10	2.05	1.53	1.28	1.36
Total	62.03	61.58	61.18	60.49	60.42	59.44	58.77	58.37	57.99	57.71

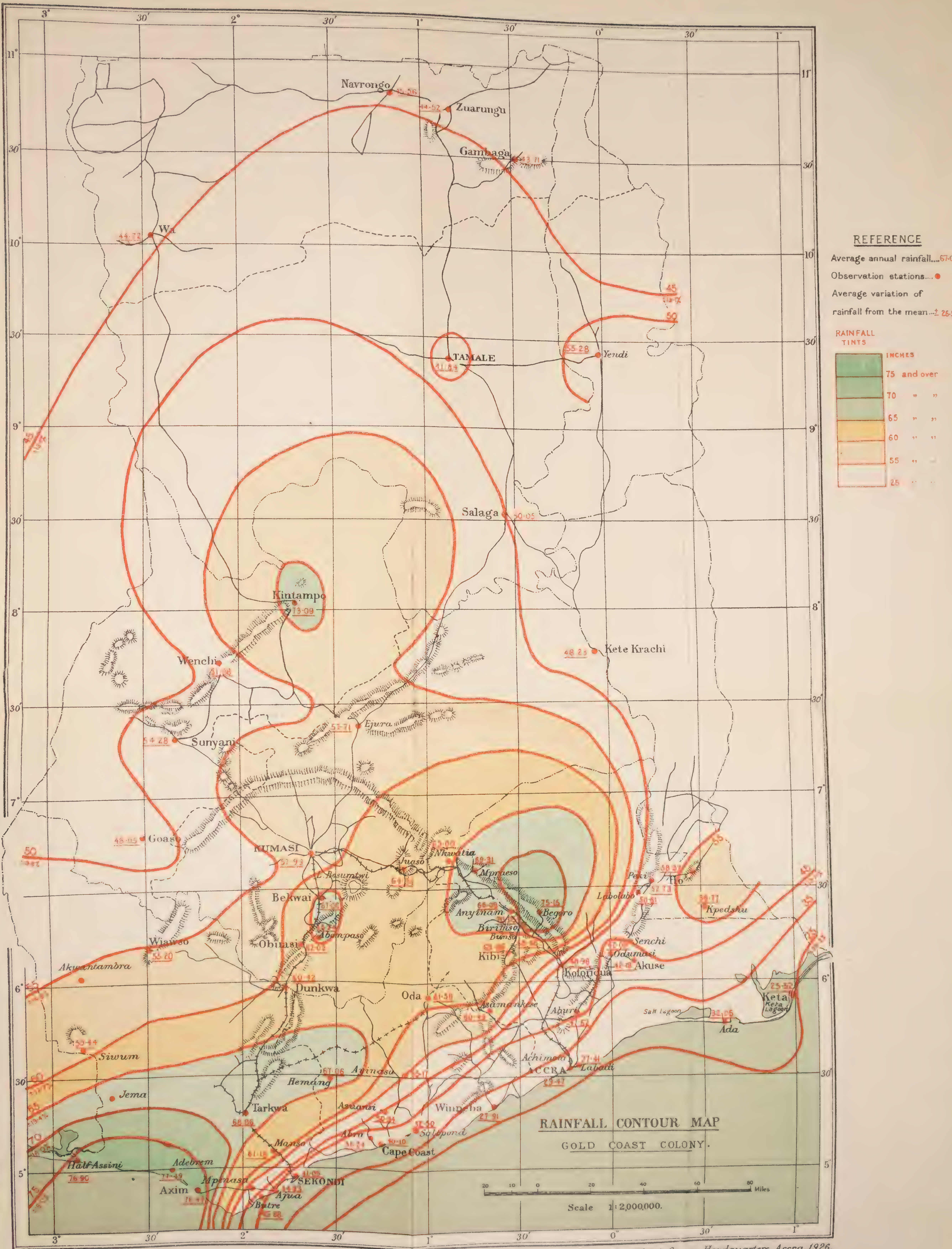
Month.	Yendi 3 years.	Wiawso 9 years.	Ayinasu 7 years.	Sunyani 10 years.	Peki Blengo 10 years.	Wenchi 3 years.	Asuansi 16 years.	Labolabo 8 years.	Salaga 10 years.
Jan. ..	1.44	1.34	3.27	.70	.73	.31	1.64	1.17	.29
Feb. ..	.28	2.10	.68	2.32	1.95	2.85	2.78	2.24	.62
March	2.02	5.79	5.49	5.19	4.01	2.82	3.90	5.09	2.37
April ..	8.57	5.07	7.01	7.04	5.53	7.76	5.76	5.88	5.14
May ..	4.37	6.82	8.00	6.21	4.57	5.00	7.27	5.77	4.96
June ..	5.49	9.08	8.00	6.31	9.37	7.25	8.58	6.97	7.29
July ..	8.19	4.69	2.97	5.04	4.76	1.88	4.36	5.18	5.59
August	3.45	2.02	1.01	2.10	3.34	1.15	2.65	3.23	6.23
Sept. ..	16.12	5.26	4.43	7.29	6.63	7.77	3.19	6.05	10.19
October	4.78	6.94	6.91	7.53	6.39	9.67	4.78	5.11	5.84
Nov.	.87	4.48	4.84	4.10	3.91	4.92	3.51	2.64	1.43
Dec. ..	.00	1.61	2.56	.45	1.47	.50	2.52	1.48	.10
Total	55.58	55.20	55.17	54.28	52.73	51.88	50.94	50.81	50.05

TABLE II.—(*contd.*)

Month.	Koforidua 3 years.	Kete Krachi 6 years.	Goaso 3 years.	Aburi 34 years.	Butre (Seysie) 4 years.	Navrongo 2 years.	Ajua 5 years.	Wa 8 years.	Zuarungu 7 years.	Gambaga 8 years.	Akuse 10 years.	Odumasi 2 years.	Tamale 15 years.	Sekondi 11 years.	Cape Coast 6 years.	Abra 3 years.
January	.51	.40	.34	1.08	1.42	.00	1.00	.59	.10	.04	.73	.62	.05	1.15	.72	.76
February ..	3.05	1.93	1.42	2.19	1.66	.00	1.49	.57	.01	.02	1.50	2.16	.23	.84	.81	.59
March	3.04	2.67	2.59	3.75	2.78	.82	2.47	1.48	.55	.83	3.69	2.90	2.67	2.44	2.53	2.71
April	5.09	4.29	9.37	5.30	3.96	2.64	3.36	3.91	4.03	2.11	5.74	3.67	3.05	4.26	4.01	2.69
May	5.67	5.03	5.63	6.15	6.59	4.68	7.48	5.04	3.25	5.25	5.66	6.67	4.59	7.90	7.21	6.99
June	9.47	7.06	6.92	7.29	12.15	7.17	11.58	5.16	6.22	5.73	6.27	8.37	5.74	7.71	9.11	10.33
July	4.10	6.63	3.96	3.71	4.02	9.48	3.55	5.71	5.42	6.14	3.33	1.53	5.32	4.15	5.85	1.66
August	.75	2.68	.56	2.20	.78	9.47	1.05	7.72	11.33	10.91	1.46	2.39	7.98	2.08	1.51	.17
September ..	5.18	8.80	4.87	3.47	2.75	10.25	1.99	9.62	10.93	9.57	4.04	3.72	8.71	1.61	1.46	1.79
October	6.87	6.23	7.26	5.64	5.51	1.05	6.63	2.78	1.92	2.04	4.56	7.28	2.69	3.93	2.69	4.51
November ..	2.88	2.17	4.65	4.66	1.60	.00	2.34	1.01	.70	.79	3.70	2.78	.68	3.56	3.03	2.31
December ..	2.37	.34	.48	2.08	2.66	.00	1.99	.68	.06	.28	1.40	.00	.13	1.37	1.16	1.73
Total	48.98	48.23	48.05	47.52	45.88	45.56	44.93	44.72	44.52	43.71	42.18	42.09	41.84	40.53	40.10	36.24

TABLE II.—(*Contd.*)

Month.	Saltpond 10 years.	Ada 7 years.	Accra 9 years.	Winneba 7 years.	Labadi 2 years.	Keta 19 years.
January	.45	.14	.58	.58	.83	.63
February	.43	.43	.56	.44	1.57	.93
March	2.47	2.25	2.09	1.55	3.40	1.45
April	3.28	3.67	3.09	2.83	3.74	2.99
May	6.88	7.36	5.27	6.43	5.73	4.52
June	8.08	7.81	6.76	6.01	3.02	5.93
July	2.53	3.10	2.45	2.12	1.09	2.06
August	.82	.82	.57	1.36	.06	.79
September	1.67	.99	2.23	1.40	1.92	1.07
October	2.69	3.46	3.83	1.96	4.28	3.09
November	2.01	1.71	1.45	1.70	.08	1.56
December	.99	.31	.59	.32	1.68	.50
Total	32.30	32.05	29.47	27.91	27.41	25.52



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A Preliminary Study of the Life-History and Habits of Sahlbergella Singularis Hagl. and Sahlbergella Theobroma Dist., attacking Cocoa on the Gold Coast, with suggested control measures.

by

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INTRODUCTION.

During the last ten to fifteen years the cocoa industry in the Gold Coast Colony has advanced by leaps and bounds until now it is the leading exporting country in the world. Until recently shortage of staff, the absence of competition, and the backwardness of the peasant farmer, have directed preventive measures against insect pests towards an attempt to induce the native grower to practice a system of clean cultivation The present paper covers life-histories and habits of the two most destructive insect pests concerned with possible controls which in the past have been impracticable.

No estimate can be made of the actual loss due to the ravages of these insects but it is known to be considerable, the death of young trees being often caused and the growth of older trees being severely checked.

In the present paper details are given of the life-histories and habits, and suggestions for control, which are the result of six months work at Asamankese in Akim-Abuakwa, where these pests are comparatively serious.

Records in a number of cases are incomplete but it must be remembered that this paper is only a preliminary investigation and not a complete study of the pests concerned. A large field of work is opened up by these results.

PLATE I.

Fig. 1.—Sahlbergella singularis. Hagl.

Fig. 2.—Sahlbergella theobroma. Dist.

SAHLBERGELLA SINGULARIS, Hagl. and S. THEOBROMA, Dist.

(Known locally as "Sankonuabe," "Akate," Cocoa Bark Sapper.")

PREVIOUS HISTORY.

In 1909, Dudgeon, who was at that time Inspector of Agriculture for the West African Colonies and Dependencies, first reported a plant-sucking bug attacking cocoa in Ashanti-Akim, ' Where careless cultivation prevailed, causing atrophy and sometimes the death of the trees ". There were found to be two species of bug causing this damage both of the genus *Sahlbergella*, family Capsidae, *Sahlbergella singularis* Hagl. and *S. theobroma* Dist. The peasant farmer had apparently realised the serious nature of the damage and named it " Sankonuabe " meaning literally " Go back to your oil palms ", palm oil being the chief agricultural product of the country previous to the establishment of cocoa.

DESCRIPTION OF SPECIES.

The adults of *S. singularis*, Plate I, fig. 1, and *S. theobroma*, Plate I, fig. 2, differ chiefly in colour. *S. singularis*, known as the speckled Sankonuabe, is much lighter in colour than *S. theobroma* being drab with light markings on the wings and legs. *S. theobroma* is black with the antonnae shorter and considerably stouter than those of *S. singularis*. The legs are also stouter and more robust. This is to be expected, *S. singularis* being a much more active species than *S. theobroma*. *S. singularis* is slightly wider across the elytra than *S. theobroma* again for the same reason.

DISTRIBUTION.

Both species are distributed throughout the cocoa-growing countries on the mainland of the West Coast of Africa. They have not been reported from St. Thomé and Fernando Po, the oldest cocoa exporting countries of the West Coast. They have also not been recorded outside West Africa. It has been suggested that the bugs may exist in these Islands but are kept under control by natural agencies to such an extent that they have been overlooked.

Local Distribution.

Both species are now distributed throughout the cocoa growing districts of the Colony, but in certain districts they are more prevalent than in others. In places outside the cocoa belt where one may find an isolated farm situated in a small remnant of rain forest the bugs are non-existent. The reason for this is most likely climatic, the conditions throughout most of the year being unfavourable to the insect.

ALTERNATIVE FOOD-PLANTS.

The only indigenous food-plants of both species are Silk Cottons (*Eriodendron* and *Bombax* spp.). On these they have only occasionally been found breeding on young trees and suckers such as are put out from silk cotton stakes that are used for fencing and from the base of fallen trees. Numerous silk cotton trees of all ages have been felled in Ashanti in badly infested districts but as yet no case has been observed of the bugs feeding on the older trees. However when its habits are taken into consideration, it is possible that *S. singularis* may at some time be found breeding on mature silk cotton trees.

S. singularis has been found at Aburi breeding freely on *Berryia amonilla*, an imported plant. It has also been reported by Mr. W. H. Patterson as breeding on cotton in the Trans-Volta district of the Colony. His attempts to breed *Salbergella* on cotton since then have failed. It has recently been reported as feeding on kola pods at Kumasi. Feeding on kola pods has never been observed by the author and previous experiments to make it feed or breed on kola pods have failed.

POSSIBILITY OF THE INTRODUCTION OF THE PESTS TO THE COLONY.

Cocoa was first imported to the Colony in 1879 and the existence of Sahlbergella first reported in 1909 by Dudgeon.* It had previously been reported in the Cameroons in 1902. It must either have changed its food-plant almost completely from silk cotton to cocoa between 1879 and 1909 or else have been introduced at some time. Specialised natural checks are exceedingly limited and because of this it was thought that possibly both species had been introduced, and that the introduction came from San Thomé or Fernando Po from which countries cocoa was originally imported in the form of pods. Although *Sahlbergella* has not been recorded as occurring in these Islands it was thought possible, that, being present only in small numbers, they had been overlooked.

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*Dudgeon G.C. Bulletin of Entom. Research. Vol. I. pt. VII. 1910.

Introduction could only have occurred in the egg stage, pods containing newly oviposited eggs being shipped. It is exceedingly improbable that introduction could have occurred in the nymphal or adult stages as it is unlikely that they could have survived the journey. Transport would have to have been sufficiently rapid to prevent hatching before arrival and a suitable food plant would have to have been available as soon as they arrived.

Against this theory are the facts that (1) two species would have been introduced, (2) that introduction would have occurred independently to most of the other cocoa growing countries on the mainland, there being no continuous cocoa or forest belt, (3) taking it that introduction could only have occurred in the egg stage, the chances of the eggs hatching neither previous to nor a few days after arrival of the pods are remote, and (4) it is probable that the majority of the pods would arrive with the pericarp, containing the eggs, in a rotten condition, in which case the eggs would fail to hatch.

It is probable that cocoa was first planted some distance apart and the intervening spaces filled up later with fresh seed. In this case young plants would be available as a food-plant, if these spaces were filled up with seeds from pods containing eggs or newly hatched nymphs.

It is possible that *Sahlbergella* species are indigenous to these Islands as well as the mainland as the fauna of the former must have been derived from the mainland. It is possible that *Sahlbergella* does occur in these Islands and is kept in check by natural enemies or climatic conditions, not existent on the mainland, to such an extent as to be overlooked. If indigenous to the mainland the pests have apparently increased, having adapted themselves to feed and breed on cocoa, in proportion to the increasing area of this crop under cultivation.

Investigations are to be made as to the occurrence of *Sahlbergella* in San Thomé and Fernando Po.

It is unlikely that they have gradually travelled up the coast from the Cameroons.

NATURE OF DAMAGE.

The feeding habits of *S. theobroma* and *S. singularis* are somewhat different. *S. theobroma* feeds and breeds on young trees from one to five years old according to the amount and nature of growth, and on pods of trees of any age. The older the wood the less likelyhood of the damage being serious. In

the case of S. *theobroma* oviposition usually takes place in first and second year wood (except under certain exceptional circumstances), the younger nymphs feeding on the newer wood. As the tree is gradually killed back the nymphs resort to older wood, and the rate of development slows down. With S. *singularis* all stages except the first feed on the older wood and the eggs are oviposited almost anywhere on the plant. Plate II, fig. 1. shows a typical young tree after one generation of S. *theobroma* has been bred up on it, and Plate II, fig. 2. a farm fourteen years old after attack by S. *singularis*.

Toxic Effect of Punctures.

When sucking up the juices from the young shoots the proboscis is inserted into the vascular system of the plant, and the sap drawn up. At the same time salivary juices are injected into the plant. The area round the punctures rapidly turns black and dies, the dead bark eventually peeling off. If the shoot does not die the strands of the dead woody tissue underneath harden up giving the characteristic riged appearance seen on most cocoa trees in this country (Plate III, fig. 1.). This remains throughout life.

Plate IV, fig. 1, 2, and 3 are a series of photographs taken of a young tree three years old on which the progeny of one female, fifteen nymphs in this case, were raised to the adult stage. Fig. 1. shows the tree before attack, fig. 2 the same tree after the last nymph has become adult, and fig. 3, two months after, no further attack having occurred in the meantime. This clearly illustrates how the toxic effect of the punctures results in dying back, which carries on long after attack has finished. It also illustrates how difficult it is to carry out control measures particularly under the casual type of cultivation employed in this country. Naturally it is no use attempting to carry out any control measures against the bugs after they have left, although this is the time when then signs of attack are most noticeable. The first sign of attack is the withering of the leaves as each shoot is sucked. Usually the leaves on the sucked shoots do not become sufficiently withered to be noticeable until attack on that particular plant has finished. The first signs of withering are brown blotches on the leaves. These usually coincide with areas where the leaf surface has been damaged, *e.g.*, areas damaged by Thrips. The swelling at the base of the leaf and where the petiole joins the stems are favourite feeding places, with the result the petiole becomes weakened and the leaf falls against the stem. This happens before the leaf withers and is another sign of the presence of *Sahlbergella*. One can expect to find the insects on the tree not later than this stage. In the case of S. *singularis* on bearing trees it is

Fig. 1.—Three-year-old cocoa plant after attack by Sahlbergella theobroma.

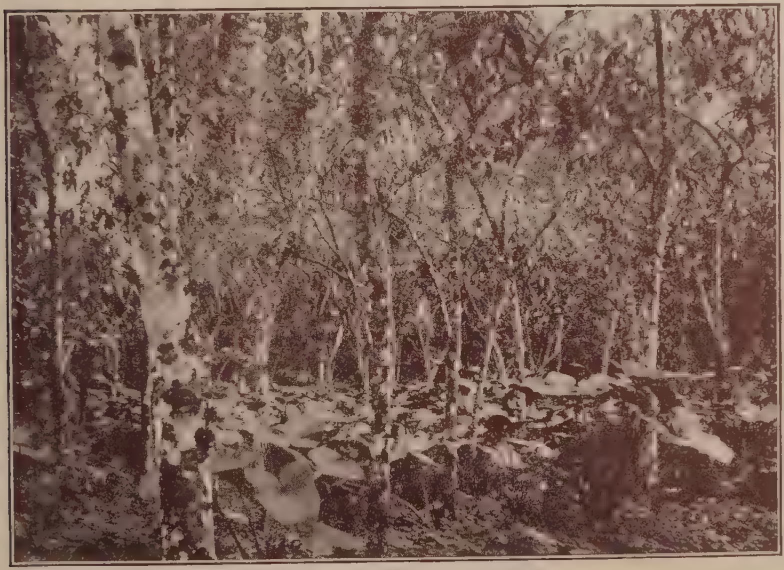

Fig. 2.—Fourteen-year-old cocoa farm after attack by Sahlbergella singularis, showing dead foliage.

PLATE III.

Fig. 1.—Appearance of bark subsequent to Sahlbergella attack when branch was young.

Fig. 2.—Appearance of Sahlbergella damage to pods.

almost impossible to discern attack until a large amount of food damage has been done. However, owing to the larger amount of material available to this species, the bugs may still be on the same trees and control measures can be carried out. It is essential that the presence of the bug be ascertained before carrying out any control measures.

Rate of Spread.

The number of bugs present is exceedingly small compared with the amount of damage done. On, say, a farm from two to five years old only about ten per cent of the attacked trees will be found to have the bugs on them. Attack commences as a general rule on the edge of a farm. Breeding commences on a very few trees and, in the case of *S. theobroma* the adults resulting from this generation oviposit on adjacent trees before migrating elsewhere. All the young wood suffers damage. Oviposition does not occur on the same tree in the same season so that the attack passes through a farm in a wave. This has been observed at Mampong, Ashanti, on a four years old farm of about 4 acres. Attack commenced on the edge of the farm and spread right through the farm as the season advanced.

In the case of *S. singularis* attacking older trees, conditions are somewhat different as one tree may be capable of supporting three or four generations.

Damage to Pods.

With both species breeding also takes place under pods, usually as the latter are approaching maturity. The proximal portion of the pod is punctured (Plate III, fig. 2). When breeding occurs on the pods fungous disease frequently results.

This type of damage should not be confused with *Helopeltis* damage to pods. *Helopeltis* punctures are spread more or less evenly over the pod, particularly the exposed portions, and are smaller than those of *Sahlbergella*. A thick layer of cork is formed over the damaged area which stands out from the surface of the pod. After *Sahlbergella* attack the punctured areas become sunken and owing to the damage being confined to sheltered parts of the pod, such as under the proximal portion where it is in contact with the stem, these areas run together.

When breeding occurs on the pods fungous disease frequently results.

SUBSEQUENT DAMAGE BY OTHER PESTS.

Plate IV, fig. 2 not only shows the final result of *Sahlbergella* attack on young trees but shows the type of new foliage put out lower down on the stem. This foliage is attacked by numerous other pests, the worst of these being leaf-eating caterpillars, Aphids and Thrips. It is only those trees that are growing under the best conditions (except for the presence of *Sahlbergella*) that this type of secondary foliage has the best chance of overcoming these pests. However the better the growth the greater the chance of a repeated attack by *Sahlbergella* at some later date.

In the case of *S. singularis* on older trees the soil shade is destroyed and secondary bush rapidly grows up, crowding out the farm. Farms are frequently left in this condition for a number of years. This results in the formation of long water shoots which, if escaping subsequent attacks, form the tall stemmy trees so often seen in bad *Sahlbergella* districts.

SEASONAL OCCURRENCE.

Both species depend on the seasonal flushes of growth and development of pods for increase. After the crop is harvested and the dry season sets in, the bug population drops as a general rule to almost negligible numbers, increasing again after the first flush of growth following the first rains.

LIFE-HISTORY DETAILS.

Owing to small differences in the life-history of both species details of each are given separately. The following data were obtained from individuals bred up on caged pods and caged trees three to four years old in the Asamankese district of the Eastern Province.

SAHLBERGELLA THEOBROMA. DIST.

OVIPOSITION.

Oviposition takes place in the cushions, pods and pod peduncles, and in first and second year wood of young trees from one to five years old, depending on the amount of wood in a suitable condition to support one generation. Occasionally the eggs are oviposited in older wood when there are green shoots or pods close by on which the newly hatched nymphs can feed. This has been observed in the case of caged pods, eggs being oviposited in cracks in the main stem which was three inches in diameter, just under a pod. This has not been observed under natural conditions. The female does not

PLATE IV.

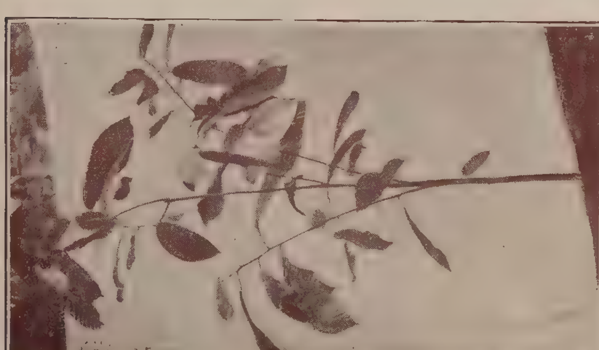

Fig. 1.—Three-year-old cocoa tree before attack by Sahlbergella theobroma.

Fig. 2.—Same cocoa tree after attack. Taken immediately after nymphs had become adult.

Fig. 3.—Same tree two months after, no further attack having occurred in the meantime.

PLATE V.

FIG. 1.

FIG. 1 (a).

FIG. 2.

FIG. 3.

FIG. 5.

FIG. 4.

FIG. 6.

EGG AND NYMPHAL STAGES OF SAHLBERGELLA THEOBROMA.

Fig. 1.—Egg (enlarged). Fig. 1a.—Showing Egg Filaments projecting from eggs embedded in pod. Fig. 2.—First Instar Nymph. Fig. 3.—Second Instar Nymph. Fig. 4.—Third Instar Nymph. Fig. 5.—Fourth Instar Nymph. Fig. 6.—Fifth Instar Nymph.

oviposit its eggs in groups, but scattered, about ten to fifteen being oviposited per pod or tree. In the case of pods eggs are oviposited as a general rule in the upper side of the cushion and peduncle and in the longitudinal ridges of the pod itself. The eggs are inserted at an angle and lie under the epidermis in a more or less horizontal position and not more than one-sixteenth of an inch under the surface. The eggs are completely buried leaving two fine hairs projecting from the surface, the longest being about one-sixteenth of an inch in length and visible to the naked eye when seen against the light. These hairs apparently serve the purpose of drawing moisture away from the egg. In the early morning a small drop of water is commonly seen at the end of the hairs apparently having been drawn up by surface tension leaving the surface of the pod or stem around the egg dry.

When oviposition takes place in young stems the egg is oviposited in the same way and lies at an angle in the cambium under the epidermis.

The egg, Plate V, fig. 1, is one-eighth of an inch long and creamy-white in colour when first laid turning brown as the incubation period advances. The incubation period varies from thirteen to sixteen days.

NYMPHAL STAGES.

The young nymph hatches out by splitting the egg-shell between the two egg filaments, and almost immediately commences to feed. The first instar nymph (Plate V, fig. 2) is approximately one-eighth of an inch long and is exceedingly active. After two to four days the first nymphal ecdysis (casting of skin commonly known as moulting) takes place. There are five moults and therefore five instars (stages between each ecdysis) before the adult stage is reached, but wings appear as small lobes on the dorsal surface of the thorax after the second ecdysis. These become larger at successive instars. The total nymphal life is from twenty to twenty-six days, and the total cycle from oviposition to adult thirty-three to forty-one days depending on the food supply. There may therefore be from seven to ten broods per annum. It is probable, however, that when the food supply is unfavourable, *e.g.*, during the dry season after the crop has been harvested, the length of the nymphal life may be considerably increased and therefore a less number of broods will occur per annum. The nymphal life is completed on individual plants, the nymphs not moving on to another plant as food becomes scarce. Details of the life history are given in Table I.

Adult Life.

The length of life of the female was also ascertained. Except in two cases the female was fed on nearly mature pods owing to the danger of losing the female in large cages over young plants. As the pods ripen, or after an excessive number of feeding punctures had been made, the females were removed to fresh pod. Natural conditions were obtained as far as possible by limiting the number of eggs laid in one caged pod to the average number of eggs laid in one pod in the field, *i.e.*, ten to fifteen.

It was found that oviposition occurs from four to ten days after the final ecdysis, the average prematurity period being seven days, and that the female was capable of living at least twenty-seven days and of ovipositing a maximum number of ninety-one eggs during this period. Oviposition occurred on the average every other day, a smaller number of eggs being oviposited each time as the female became older. During the last three or four days of life torpidity set in. Some difficulty was encountered on occasions in obtaining the necessary males. Immature males caged with mature females were invariably killed. Late in the evening it was observed that males from the field were attracted to cages containing mature females but no males. Copulation was not observed to take place during the day under field conditions but it occasionally took place during the day in the cages, oviposition taking place at night.

TABLE I.—SUMMARY OF INSTAR PERIODS OF SAHLBERGELLA THEOBROMA.

Field Cage No.	Incubation Period.	1st instar Period.	2nd instar Period.	3rd instar Period.	4th instar Period.	5th instar Period.	Nymphal Life.	Cycle Egg to Adult.	Where Bred.
71	15 days	—	—	—	—	—	22 days.	37 days.	Young Tree.
88	14–15 days.	2 days.	5 days.	(4 days ?).	(3 days ?).	(6 days ?).	20 days.	34–35 days.	Pods.
91	13 days.	2 days.	3 days.	5 days.	4 days.	6 days.	20 days.	33 days.	Pods.
93	14 days.	(3 days ?).	(3 days ?).	8 days.	4 days.	6 days.	24 days.	38 days.	Pods.
99	13 days.	(4 days ?).	(3 days ?).	3 days.	5 days. ..	6 days.	21 days.	34 days.	Pods.
100		(4 days ?).	(1 day ?).	5 days.	5 days.	6 days.	21 days.	—	Pods.

TABLE I.—SUMMARY OF INSTAR PERIODS OF SHALBERLIA THEOBROMA.—*(contd.)*

Field Cage No.	Incubation Period.	1st instar Period.	2nd instar Preriod.	3rd instar Period.	4th instar Period.	5th instar Period.	Nymphal Life.	Cycle Egg to Adult.	Where Bred.
104	14 days.	(2 days ?).	(1 day ?).	4 days.	4 days.	7 days.	18 days.	32 days.	Pods.
106	13 days.	4 days.	4 days.	3 days.	4 days.	5 days.	20 days.	33 days.	Pods.
109	14 days.	3 days.	4 days.	4 days.	4 days.	6 days.	21 days.	35 days.	Pods.
110	14–15 days.	3 days.	5 days.	9 days.	4 days.	5 days.	26 days.	40–41 days.	Young Tree.
114	14 days.	6 days.	3 days.	4 days.	4 days.	—	—	—	Young Tree.
116	16 days.	—	—	—	—	—	—	—	Pods.

TABLE I.—SUMMARY OF INSTAR PERIODS OF SHALBERGELLA THEOBROMA.—*(contd.)*

Field Cage No.	Incubation Period.	1st instar Period.	2nd instar Period.	3rd instar Period.	4th instar Period.	5th instar Period.	Nymphal Life.	Cycle Egg to Adult.	Where Bred.
117	13–14 days.	4 days.	3 days.	4 days.	5 days.	—	—	—	Pods.
129	14 days.	4 days.	3 days.	3 days.	—	—	—	—	Pods.
137	14 days.	2 days.	4 days.	4 days.	—	—	—	—	Pods.
Average ..	14 days.	3–4 days.	3–4 days.	4–5 days.	4 days.	6 days.	21–22 days.	35–36 days.	—

NOTE.—Where figures are given in parenthesis the length of that period **was not** definitely ascertained and is not included in the averages.

TABLE II.—OVIPOSITION AND ADULT LIFE RECORDS OF S. THEOBROMA.

Caged No. (last ecdysis).	Prematurity Period.	Total No. of Ovipositions.	Most Eggs at one Ovip.	Total No. of Eggs Oviposited.	Life of Female.	Remarks.
74	6 days.		Not recorded.			*Female lost. Escaped from Cage.
99	6 days.		Not recorded.			‡First oviposition. Eggs did not hatc . Apparently infertile.
101	10 days.	Not recorded.		36 §	27 days*	§Experiment done on young plant, and possibly a number of eggs not observed.
116	4 days.		Not recorded.			MINIMUM PREMATURITY PERIOD = 4 DAYS. MAXIMUM PREMATURITY PERIOD = 10 DAYS.
117	5–6 days.	11	10‡	74	19 days.	MAXIMUM NO. OF EGGS AT ONE OVIPOSITION = 22 MAXIMUM NO. OF OVIPOSITIONS = 16
129	5 days.	16	10	90	26 days.	MAXIMUM NO. OF EGGS OVIPOSITED = 91
134	5–6 days.	15	22	91	27 days.	MAXIMUM LIFE OF FEMALE=27DAYS.

Occurrence of Sexes.

Females were found to be more abundant in the field than males, although the sexes were bred out in approximately equal numbers. No definite experiments were carried out as to the life of the adult male, but other experiments indicated that it is considerably shorter than that of the female and this would account for the prevalence of females in the field.

Details of oviposition and adult life records are given in Table II.

SAHLBERGELLA SINGULARIS. HAGL.

Oviposition.

S. singularis may oviposit almost anywhere in the plant older wood being apparently preferred. Eggs have been observed in main stems. When caged on pods oviposition took place as a general rule in the cushion or old cushions or in the main stem. Eggs were only occasionally oviposited in pods and peduncles. The eggs are much more scattered about the tree than is the case with *S. theobroma* owing to the less localised feeding areas of the nymphs. Owing to the position of the eggs it was not possible to obtain such definite life-history records as with *S. theobroma*, as in most cases the eggs were not observed.

The egg of *S. singularis* is idenitcal with that of *S. theobroma* but the position in which the egg is laid is somewhat different. When laid in green shoots the egg is laid at an angle, as with *S. theobroma*, but when laid in thick twigs, branches and cushions, the egg is placed in almost a vertical position. This is due to the bark and cambium being thick enough to take the egg in this position, whereas when oviposited in young wood one to two years old and in peduncles of pods the position of the egg is due to the bark and cambium being comparatively thin. The ovipositor is apparently unable to pierce the cortical layer, or else this piercing would result in distortion of the egg.

The incubation period is from fourteen to seventeen days.

Nymphal Life.

There are five instar periods as in the case of *S. theobroma*, the wing lobes first appearing in the third instar. The adult stage is reached after twenty-three to twenty-four days of nymphal life and the total cycle from egg to adult is from thirty-six to thirty-nine days.

TABLE III.—SUMMARY OF INSTAR PERIODS OF S. SINGULARIS.

Field Cage No.	Incubation Period.	1st Instar Period.	2nd Instar Period.	3rd Instar Period.	4th Instar Period.	5th Instar Period.	Nymphal Life.	Cycle Egg To Adult.	Where Bred.
80	(14–15 days ?)	(3 days ?)	(3 days ?)	(4 days ?)	(9 days ?)	(4 days ?)	23 days	37–38 days	Young Tree.
86	—	2 days	3 days	(8 days ?)	(6 days ?)	(4 days ?)	23 days	—	Young Tree.
98	15 days	(5 days ?)	(1 day)	5 days	6 days	7 days	24 days	39 days	Young Tree.
108	—	2 days	—	—	—	—	—	—	Young Tree.
127	17 days	5 days	—	—	—	—	—	—	Pods.
138	17 days	2 days	3 days	3 days	4 days	—	—	—	Pods.
144	15 days		—	—	—	—	—	—	Pods.
Average ..	16 days	3 days	3 days	4 days	5 days	(7 days)	23 days	38 days	

NOTE.—Where figures are given in parenthesis the length of that period was not definitely ascertained and is not included in the average.

PLATE VI.

FIG. 1.

FIG. 2.

FIG. 3.

NYMPHAL STAGES OF SAHLBERGELLA SINGULARIS.

Fig. 1.—Third Instar Nymph.
Fig. 2.—Fourth Instar Nymph.
Fig. 3.—Fifth Instar Nymph.

Details of the life-history are given in Table III.

DESCRIPTION OF NYMPHS OF BOTH SPECIES.

The full-grown nymphs of both species are shown in fig. 6 and Plate VI fig. 3.

Plate V. As the habits of the two species differ it is important that they should be recognised in the field. A description of both is given below.

S. THEOBROMA.—General colour dark pink-brown Antennal joints short and only about two-thirds the length of antennal joints of *S. singularis*. Penultimate and ultimate joints of antennae round. Black.

Dorsal surface of thorax and abdomen flat. Markings on dorsal surface of latter not very conspicuous. Abdominal segments not well differentiated. Legs shorter and stouter than those of

S. singularis, particularly the hind tibiae.

A more robust species than *S. singularis*.

S. SINGULARIS.—General colour dark brown. Antennal joints considerably longer than those of *S. theobroma*, particularly the second. Penultimate and ultimate joints oval. Black.

Dorsal surface of thorax and abdomen rounded. Markings on dorsal surface of latter dark and conspicuous. Abdominal segments well differentiated on dorsal surface. Ventral surface of abdomen speckled. Legs longer and more slender than those of *S. theobroma*. Distinctly speckled.

A more active species than *S. theobroma*.

The most distinctive differences are the length of the antennae and shape of the two distal antennal joints, and the flattened appearance of *S. singularis* as compared with *S. theobroma*.

HABITS IN THE FIELD.

As has been stated earlier the habits of *S. singularis* and *S. theobroma* differ. *S. theobroma* breeds on trees six or seven years old and younger and also under pods on bearing trees in proximity to young farms, whereas *S. singularis* breeds on trees of any age, but as a general rule on trees over six years of age, and under pods. This is indicated by the oviposition data of each species. It is therefore obvious that *S. singularis* is the most important pest.

Feeding commences shortly after hatching and in the case of *S. theobroma* the nymphs of the earlier instars feed on green pods only. As the nymphs get older and the green shoots commence to wither they feed on the previous season's wood and eventually, if there is not sufficient younger wood present, on still older wood. In this case the instar periods are prolonged. In no case do the nymphs move from tree to tree except where the branches happen to be in contact. With *S. singularis* feeding takes place in the younger stages on leaf petioles and twigs and occasionally under pods. They are also capable of supporting themselves on much harder wood. The older nymphs feed on wood possibly two to three years old, and after a heavy attack when most of the younger wood has been destroyed, on developing pods. Climatic conditions and the state of the food plant favour increase of the pest just before the pods are maturing, so that when food becomes short or unfavourable there is an ample supply of more suitable food available in the nature or maturing pods. This may also occasionally be followed by a further attack on the branches owing to the nymphs moving up again after the pods have been harvested. *S. singularis* is also capable of supporting itself on wood as much as fourteen years old, if no more favourable food is available. In this case practically no damage is done and the life-history is prolonged.

The nymphs and adults of *S. singularis* are much more active than those of *S. theobroma* on account of the larger area of the food plant upon which they feed, and the smaller amount of sutiable food in one particular place on the older trees.

The adults of *S. theobroma* are considerably slower in flight than those of *S. singularis* and do not go far from the place in which they were bred if sufficient material suitable for oviposition is available near by, this operation taking place on these adjacent plants, whereas the adults of *S. singularis* will search over considerable distances for favourable places to oviposit. Further work will be undertaken on the rate of spread of *S. singularis* as compared with that of *S. theobroma*.

Feeding only takes place during the early morning, late evening and night, except on dull days and on densely shaded farms, the nymphs hiding themselves in the cracks and axils of branches during the heat of the day. The adults are only seen on the wing during the cool of the day except when disturbed, when only short flights to adjacent plants are made. When disturbed the adults have the habit of dropping nearly to the ground before taking wing. This habit is more marked in *S. theobroma* than in *S. singularis*.

FIELD CONDITIONS FAVOURABLE FOR ATTACK.

It is an indisputable fact that *Sahlbergella* will not attack every farm. Certain farms appear to present unknown conditions which are favourable for breeding. It was at first thought that this was more due to the age of the farm than anything else. This was before it was realised that the habits of the two species differed. It was in those areas where *S. theobroma* was most prevalent that this theory was first entertained. Since then in the case of *S. singularis* it has been found that age is not a determining factor. It has been observed that certain farms, usually in particular districts, may suddenly be attacked by *S. singularis* for no apparent reason, there being a large number of farms in the immediate neighbourhood with no signs of *Sahlbergella* attack. While farms growing in badly drained areas and sandy soil are as a general rule infected, attack is by no means confined to them. However, it has been observed that the majority of farms growing in those districts where a light sandy soil is prevalent are more prone to attack than those growing in districts where a red loam is the predominant type of soil. Whether this is due to the mechanical or chemical constitution of the soil is not yet known. It has been suggested to the author that severity of attack may be related to the chemical constitution. With Tea *Helopeltis* in India, E. A. Andrews* has done a considerable amount of work regarding chemical constitution of the soil and resistance to attack, and it is proposed to follow up some of his lines of work here.

The question of the age of trees appears only to apply to *S. theobroma.*

CONTROLS.

Natural Controls.

Natural controls of *Sahlbergella* spp., such as internal parasites and specialised predators, are exceedingly limited in number and effect. The lack of specialised controls first suggested the possibility of *Sahlbergella* spp. having been imported and their natural enemies having been left behind in the country of origin. Since then a number of casual predators have been found and one internal Hymenopterous parasite of *S. singularis.* The latter has not yet been determined. Casual predators consist of Mantid nymphs, an occasional Reduviid predator, spiders and lizards. Of

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* Andrews E.A. Factors affecting the Control of the Tea Mosquito bug, 1923. Indian Tea Association.

these, spiders and lizards, particularly the night feeding lizards, are the most important. On young trees liable to, or in process of being attacked by *Sahlbergella*, there is a species of spider which forms a small tent of silk in the axils of leaf petioles and branches, under which it lives. It apparently lives exclusively on *Sahlbergella* nymphs, pouncing on them when they come to seek shade and protection during the heat of the day.

The importance of insectivorous birds has not yet been ascertained but is is probably considerable.

One Hymenopterous parasite has been bred out from, *S. singularis* at Asamankese, and some time ago at Aburi parasitisation at the former place not exceeding three per cent. This parasite has not yet been determined. Specimens obtained from Aburi failed to emerge from their cocoons. The full-grown larva of the parasite emerges from the fifth instar nymph of *S. singularis* and pupates in the vicinity of the dead host. Owing to the end of the season limiting the amount of material available, details as to the place of pupation, etc. have not yet been ascertained, but it is presumed that the dead nymphal host falls to the ground before emergence of the parasite, pupation of the latter taking place in the ground. Work on details as to the life-istory and habits of this parasite are in hand.

Another Hymenopterous parasite, *Encyrtus cotterelia*, Waterst., (vide Bull. Entom. Res. Vol. XIII., part 2,) was bred out in 1921 in Ashanti from *S. theobroma*, but as only three specimens were obtained it is considered of no importance at present. No further specimens have been obtained elsewhere.

CULTURAL CONTROL MEASURES.

In the case of possible attack by *S. theobroma*, giving young plantations the very best cultivation possible until at least five years old in order to give the trees the best chance during this critical period when they are most subject to attack, will render the trees more resistant to serious damage when attack does occur.

It is impossible to give any definite ruling as to cultivation of older farms subject to attack by *S. singularis*. In districts where this species is known to be prevalent the best attention should be given to shade, drainage, and preservation of the surrounding forest trees. This will not make a farm less liable to attack, but will result in less actual injury when attack does occur.

ARTIFICIAL CONTROL MEASURES.

Artificial control measures are confined at present to hand-picking and spraying or dusting.

If a daily inspection is made in young farms from one to five years old it should be a simple matter to control *S. theobroma*. As has been stated earlier on, infection almost always commences by a single female ovipositing in one or two trees on the edge of the farm during the growing season, *i.e.*, between March and the end of September. It takes seven weeks from the time of oviposition for the nymphs resulting from these eggs to become adult. Wilting may first be noticed before the adult stage is reached, the nymphs killed by hand on the infected trees, and attack on any further trees thus prevented. If wilting is not observed before some bugs have reached the adult stage, oviposition will have taken place on adjacent trees. These trees must be carefully watched for the nymphs to hatch out, and killed as well as any original nymphs on the trees on which the attack started. If this is not done it is more than likely that the attack will spread right through the farm.

Hand-picking is useless as a control measure for *S. singularis*, as it is impossible under ordinary conditions to locate more than a very few of the bugs. However, from September to November when the crop is maturing, a large number can be found under pods. Oviposition has occurred in this position, or as is usually the case the nymphs have descended to a more favourable food-material. In this position they are accessible and can be killed by the application of a strong insecticidal wash. A wash made of kerosene emulsion made as follows is effective :—

Kerosene	..	2 gallons
Soft soap	..	2 lbs. (or bar soap—1 lb.)
Water	..	1 gallon.

Dissolve and boil the soap in the water. Add the kerosene when the soap solution is boiling. Use one part to fifteen of water. The wash can be applied by means of a powerful hand syringe.*

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*Taking fifteen as the average number of pods per tree and a gallon of solution as capable of charging a powerful hand syringe eight times, two gallons of solution will be required per tree. The average cocoa farm contains approximately 450 trees per acre. Thus 900 gallons will be required per acre, if all the pods are affected—which is improbable—at a cost of £2 exclusive of labour. It is probable that only about twenty per cent of the pods will be affected and the cost considerably reduced.

Spraying and Dusting.

When an attack by *S. theobroma* has spread so far as to make hand-picking impracticable, or at the commencement of an attach by S. *singularis* on maturing trees—spraying or dusting must be resorted to. First of all it is essential to ascertain if the bugs are still present on the farm. In the case of *S. theobroma* if the attack is allowed to go too far it will be found that though possibly all the trees have suffered only a few may have the bugs actually on them and it will be necessary to treat the whole farm, with a consequent waste of time, labour, and material. With *S. singularis* attack on mature trees it is probable that the bugs will be actually on the trees during the whole of the attack, *i.e.*, during the whole of the rainy season, and spraying or dusting can be carried out with success at any time during this period. The earlier the first application the better as the affected area will be limited and there will be a better chance of totally eliminating the pest on that farm.

Spraying or dusting should be carried out in the early morning or evening when the bugs are active, otherwise the majority of them will be hiding in cracks in the branches and will thus be protected.

Owing to the suctorial habit of the bugs the spray or dust must be a contact poison. At present the only practicable contact insecticides for this country are Nicotine Sulphate, Kerosene Emulsion and possibly Lime Sulphur. The latter is ruled out for use against *Sahlbergella* on account of the low mortality it produces and danger of burning. Kerosene emulsion at ordinary strengths also produces a low mortality when used against *Sahlbergella* and if kept for any length of time as a stock solution causes burning owing to free kerosene separating out. Nicotine sulphate can be used as a spray or dust and is the most successful insecticide tried out as yet against *Sahlbergella*. A nicotine water spray is more efficient than a nicotine dust but the former has certain disadvantages which are enumerated later on. A nicotine water spray used in the proportion of one ounce of nicotine sulphate (40%) to six gallons of water (1 : 1,000), with the addition of soap to emulsify the solution, will account for 100% of the bugs if applied to completely cover each tree.

The formula for making the above is :—

> Boil six gallons of water with ¼ lb. of hard soap or ½ lb. of soft soap.
>
> When boiling add 1 oz. of 40% nicotine sulphate. *
>
> Stir and allow to cool before applying.

---

* "Black Leaf" "40" (Nicotine sulphate 40%) sold by "The Tobacco By-Products and Chemical Corporation," Louisville, Kentucky, U.S.A., at a cost of $ 13.50 per ten pound tin f.o.b. Louisville.

Nicotine dusts are as a rule already made up for use and therefore require no mixing. If applied with a good machine in a heavy cloud the mortality reaches about 80%. This drop in percentage efficiency is due to contact not being so good as with a liquid nicotine spray.

At present the only nicotine dust which has been tried out locally is a dust put up by an American firm* which is somewhat expensive for use in this country. The cost of applying a dust is at present higher than that of a spray, but the former has the advantage of being already prepared, it will do considerably more on one charge of the machine than a spray, is less unwieldy to carry about and is more effective in proportion to the amount of material used on trees twelve feet high or over.

A gallon of a liquid spray will cover approximately ten to twelve trees averaging five feet in height and thirty or forty leaves per tree. At double this height approximately four times this amount will be required. This means that taking the average charge of a spraying machine as two gallon only twenty odd trees averaging five feet in height can be done per charge and only five averaging ten feet in height. For full grown trees as much as four gallons may be required per tree. This entails a large amount of labour in walking backwards and forwards to the re-filling station and ready supply of water is usually not available near the average cocoa farm.

With a dusting machine ten to twenty pounds of dust can be carried in one charge. Eight to ten pounds of dust are required per acre for trees averaging five to six feet in height planted twelve feet apart, and about thirty pounds for trees double this height.

Investigations are being made as to the possibility of an efficient dust being made in this country. With a small plant for mixing the material it is possible that the cost of effective dusts may be considerably reduced. A home-made dust mixer, consisting of a barrel mounted as illustrated in Plate VIII. fig. 1, is recommended in the United States. The

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2. "California Sprayer Co., Los Angeles, California, U.S.A., Calispray dust No. 15 containing 7½% standard 40% nicotine extract. Approximate cost of this dust is $ 24.63 per 100 lbs. drum f.o.b. Los Angeles. (less 25% discount).

Nicotine dusts are also put up by the "Tobacco By-Products and Chemical Corporation," Louisville, Kentucky, U.S.A. This firm manufacture a dust containing 2% actual nicotine or 5% "Black Leaf 40" known as F 1 nicotine dust, at a cost of $ 8.25 per 100 lbs. f.o.b. Louisville, Kentucky. This dust has not yet been tried out locally but shows a substantial saving over the Calispray No. 15 dust. This firm has the full recommendation of the United States Department of Agriculture.

required amount of hydrated lime is put in the barrel and the necessary amount of nicotine sulphate added to make the required strength of dust, *i.e.*, $3\frac{3}{4}$ lbs. or three pints of nicotine sulphate to 50 lbs. of hydrated lime to make $7\frac{1}{2}\%$ strength dust.* Pieces of rock or pebbles are used inside the barrel to effect better mixing. The barrel is then rotated slowly for at least five minutes to ensure mixing of the materials. An advantage of making nicotine dusts on the spot is that the material does not suffer deterioration during storage. Unfortunately owing to a good quality of lime not occurring in the Colony this commodity would have to be imported with a proportionate increase in cost.

Plate VII. shows a duster at work on trees fifteen feet in height and gives an idea of the advantage a dust has over a liquid spray at this height.

Dusting must be carried out when there is no wind or practically none, otherwise a large amount of material will be blown away and lost.

For spraying the best machine is a "Four Oaks" Knapsack Sprayer with external hand pump. Pressure machines give a better spray and require less labour in manipulating but are liable to be overcharged and broken.

A dusting machine must be a good machine with strong bellows and an efficient agitator. Such a machine is illustrated in Plate VIII., fig. 2.†

SUMMARY.

Sahlbergella singularis and *S. theobroma* have only been reported as occurring in the cocoa growing countries on the mainland of the West Coast of Africa, and not in the Islands of San Thomé and Fernando Po, the oldest cocoa growing countries of the West Coast.

The first record of attack on cocoa by these bugs was in 1902 when they were reported from the Cameroons. The first record of their occurrence in the Gold Coast was by Dudgeon in 1909. The possibility of the bugs having been

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* Using a strength of 3% (actual nicotine) or $7\frac{1}{2}\%$ "Black Leaf 40" (Tobacco By-Products and Chemical Corp.) cost of manufacturing in the United States would be $ 11.05 per 100 lbs. As lime would have to be imported the cost of manufacturing in the Colony would be increased by freight on "Black Leaf 40" and hydrated lime.

† Constructed by the "California Sprayer Co.," Los Angeles, California U.S.A. at a cost of $ 25.00 f.o.b. Los Angeles.

The "Bean Spray Pump Co." of Lansing Michigan, U.S.A. manufacture a machine known as the "No. 1 Acme Duster" at $ 18.00 f.o.b. Lansing, Michigan. This machine has not been tested in the Colony but is to be recommended owing to there being no outside gearing.

PLATE VII.

Knapsack dusting machine at work on cocoa tree over fifteen feet in height.

PLATE VIII.

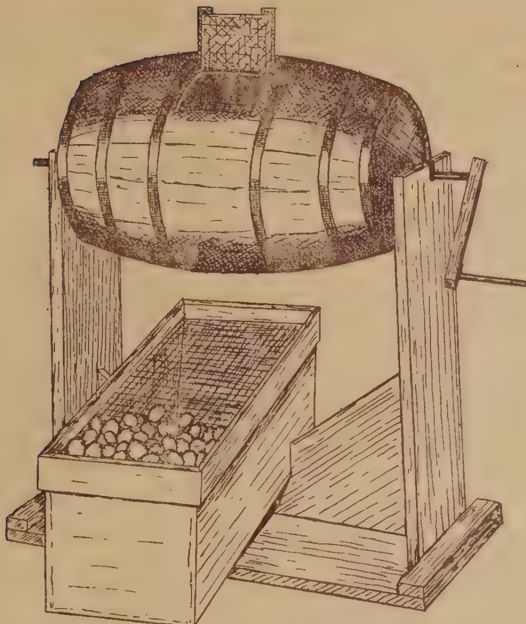

FIG. 1.

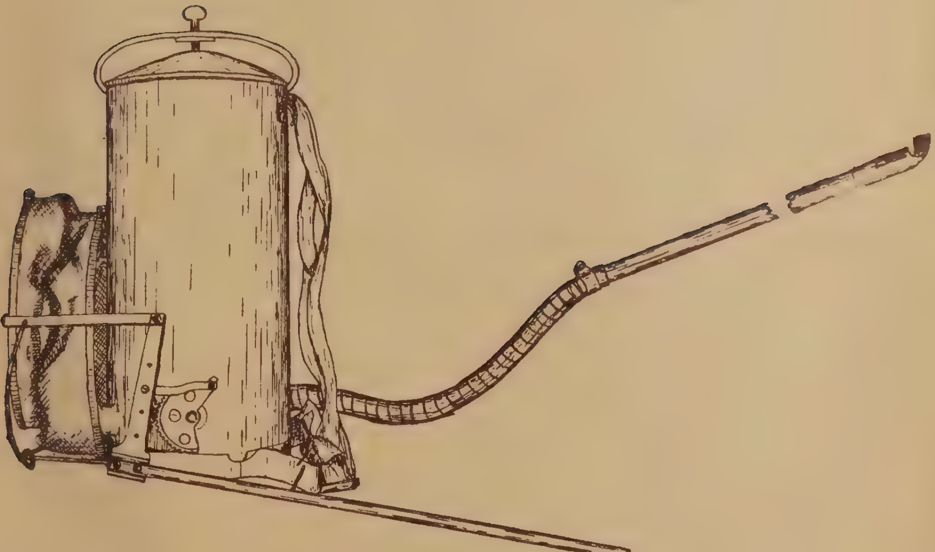

FIG. 2.

Fig. 1.—Home-made Dust Mixer for mixing Nicotene Sulphate and Hydrated Lime.

Fig. 2.—Knapsack Duster constructed by California Sprayer Company, U.S.A.

imported from the Islands of San Thomé and Fernando Po, where their occurrence may possibly have been overlooked, without their natural enemies, has been considered. The theory of importation is supported by the fact that specialised natural checks are uncommon. It is thought that importation could only have occurred in the egg stage, eggs being imported with the pods. Hatching would have to have occurred almost immediately on arrival of the pods at their destination and a suitable food plant would have to have been available close by.

It is thought more probable that the pests may be indigenous to both these Islands and the mainland having originally fed on young Silk Cottons prior to the introduction of cocoa and have reached the proportions they now occupy in the cocoa growing countries of the mainland owing to the greatly increased cultivation of the crop, whereas in San Thomé and Fernando Po they are kept in check by natural agencies such as natural enemies or climatic conditions.

Damage is caused by the adults and nymphs sucking stems and shoots up to two or three years old, resulting as a rule in the subsequent death of the part affected. The bugs have been found to have some toxic effect on the plant which carries on long after the original injury has occurred. This effect is produced by the introduction of some toxic substance with the salivary juices at the time of puncturing.

Each species has been found to differ somewhat in habits, *S. singularis* attacking trees of any age, usually those of six years old or over, whereas *S. theobroma* is confined to young trees from one to five years old and developing pods of older trees growing on the vicinity of young trees. Both species breed on the suckers of Silk Cottons, *Eriodendron* and *Bombax* spp. They have also been observed breeding on *Berryia amonilla*, an imported plant.

S. singularis oviposits in shoots, and in branches of cocoa of almost any age, as long as there is sufficient young growth close at hand on which the newly hatched nymphs can feed. This species also oviposits occasionally in cushions and peduncles, and in the pods themselves.

S. theobroma oviposits in second and third year wood, except in exceptional circumstances, and in the cushions and peduncles of maturing pods, as well as in the pods themselves.

The life-history of both species is similar. The egg stage of *S. theobroma* lasts approximately fourteen days and that of *S. singularis* approximately sixteen days. The nymphal life of both species varies according to the state of the food material, the minimum period being eighteen and the maximum twenty-six days. The total period from egg to adult varies from thirty-two to forty-one days. The prematurity period of the adult female of *S. theobroma* was

found to average six days making a total cycle from egg to egg averaging forty-two days. The female of *S. theobroma* was found to be able to live under caged conditions for at least twenty-seven days, and to lay at least ninety-one eggs during this period.

The nymphs and adults of both species are inactive during the heat of the day, hiding themselves in crevices and the axils of the branches and under pods, feeding taking place during the night, early morning and evening. In the case of *S. theobroma* oviposition occurs for the most part on adjacent food-plants to those on which the female originated whereas *S. singularis* will go some distance to oviposit. *S. singularis* is a considerably more active species than *S. theobroma* both in the nymphal and adult stages. Both species are found congregating under maturing pods of bearing trees a month or two previous to the harvesting of the crop.

Both species depend on the seasonal flushes of growth and development of pods for increase. Cocoa growing on light sandy soils is more prone to attack than that growing on the red clay loams.

Natural controls are not common. An internal nymphal parasite and a spider which is predaceous on the nymphs are apparently the only specialised checks.

Cultural control measures consist of keeping the cocoa plant in the best of health. Healthy trees although no less liable to attack have a better chance of overcoming the attack than unhealthy trees. Every chance should be given to young cocoa trees to hasten them over the period when they are liable to attack by *S. theobroma.*

The only artificial control measures that are likely to be of use are spraying or dusting with nicotine sulphate. Dusting is recommended in preference to spraying on account of it being possible to treat tall trees and because it obviates the difficulty of obtaining water and boiling up the necessary emulsion required for a spray. A dusting machine is also considerably less unwieldy than a spraying machine and covers a larger area per charge. The only dust so far experimented with is a dust containing seven and a half per cent nicotine sulphate (40%). This was found effective but costly. It is thought possible that a dust can be made locally at a considerable reduction in cost, such a dust being probably more effective owing to the liability of loss of nicotine from made up dusts when kept for any length of time.

A strong wash of kerosene emulsion can be effectively applied with little fear of burning when both species are congregating under pods previous to the harvesting of the crop.

G. S. COTTERELL,

Government Entomologist.

Types of Cacao grown at Wiawso, Western Province.

FOREWORD.

CACAO, the chief crop of the country, has naturally been the chief crop on the Stations of the Department. The results are to be found in the Annual Reports of the Department which this Bulletin summarises.

In the text will be found a reference to what may seem the omission of a very important part of the work of a Department of Agriculture—the neglet of manurial experiments. With the phenomenal growth of the cacao industry here, an industry in which the methods to be used were so entirely strange to the farmers, who generally farm quite small areas and most of whom are illiterate and with the enormous area to be covered the first need was a large number of nurseries and plots where seed would be available and the methods of planting and curing the crop could be demonstrated. Nothing was attempted which the farmers themselves could not adopt. The work accomplished under the direction of my predecessor, Mr. W. S. D. Tudhope, has been of very great benefit to the industry.

Changes are now contemplated in the work on the stations and in the stations themselves, hence the present time is a suitable one for publishing in a concise form the results obtained.

The main part of compiling the tables and the text was done by Mr. G. G. Auchinleck, Deputy Director, but was not completed when he had to leave the Colony on a special mission; the small amount necessary to complete the Bulletin has been done by the Director.

C. H. KNOWLES,
Director of Agriculture

Accra, 20th April, 1926.

YIELDS OF CACAO ON EXPERIMENT STATIONS.

The earliest recorded date of the introduction of the cacao plant into the Gold Coast is 1879, in which year a farmer brought seeds from Fernando Po and planted them at Mampong near Aburi.(1)* Since that date the area of farms has increased until it has now extended to an estimated total of some 900,000 acres.(2)

It seems probable that the type first introduced was a yellow-podded Amelonado, and this type still predominates in all parts of the country. The type is hardy and thrives under conditions of drought and neglect in the Gold Coast which would probably prove too severe for more delicate kinds.

In 1901 (3) plants of *Pentagona cacao* (alligator cacao) were forwarded to the Gold Coast from the Royal Botanic Gardens, Kew, and an area was established at Aburi Experiment Station. As in the West Indies, this variety has proved to be too delicate and its cultivation has been abandoned. In 1905 (3) plants of the Ocumare type were introduced and established, and in 1906 (3) an area of Cundeamor type was established. Finally plants of the Criollo variety were imported from the West Indies in 1909 (3) and set out in a plot at Aburi.

The classification of varieties and types of cacao can be found in Van Hall's book.(4) Suffice it here to say that *Theobroma* is the generic botanical name of cacao and that among the numerous species we find *Theobroma cacao* and *Theobroma pentagona*. The former includes three well-recognised commercial varieties, the hardy, inferior Calabacillo, the moderately hardy Forastero of medium quality, and the delicate superior Criollo.

The frontispiece of this Bulletin shows five types grown at Wiawso Experiment Station in the Western province of the Gold Coast, arranged in order of merit. Of these the Amelonado, Ocumare and Cundeamor appear to be fairly true to type, while the Calabacillo differs from its type by the presence of a constriction (bottle-neck) near the base.(5) The Criollo pod is not characteristic in shape of the ordinary

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* For references to literature quoted see page 15.

Venezuelan and Nicaraguan types. Amelonado and Cundeamor are generally recognised to be varieties of Forastero, while Ocumare is stated by Hart to be a form of Venezuelan Criollo.

There is no record of the importation of Calabacillo into the Gold Coast and it was presumably brought in along with Amelonado from Fernando Po.

Experiment Stations.

The experiment stations of the Gold Coast at which fields of various types of cacao have been established, and from which records have been obtained for this Bulletin, are as follows :—

Aburi :—Founded in 1890. Distance from sea 20 miles. Elevation 1,450 feet. Rainfall from 32.09 to 73.16 inches with an average for 34 years of 47.52 inches.

*Tarkwa** :—Founded in 1902. Distance from sea 32 miles. Elevation 300 feet. Rainfall from 48.22 to 95.03 inches, with an average for 21 years of 68.86 inches.

Kumasi :—Founded in 1906. Distance from sea 112 miles. Elevation 850 feet. Rainfall from 40.07 to 70.40 inches, with an average for 18 years of 57.99 inches.

Asuansi :—Founded in 1907. Distance from sea 14 miles. Elevation 330 feet. Rainfall from 41.28 to 74.17 inches, with an average for 16 years of 50.94 inches.

Kibi :—Founded in 1912. Distance from sea 48 miles. Elevation 940 feet. Rainfall from 45.77 to 79.90 inches, with an average for 12 years of 63.86 inches.

Peki-Blengo :—Founded in 1913. Distance from sea 53 miles. Elevation unknown. Rainfall from 36.33 to 68.46 inches, with an average for 11 years of 52.73 inches.

Wiawso :—Founded in 1915. Distance from sea 86 miles. Elevation 850 feet. Rainfall from 40.14 to 70.44 inches, with an average for 9 years of 55.20 inches.

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* The figures of yields at this station are not included in this Bulletin : conditions were so unfavourable that the cacao trials were abandoned at an early date.

Kpeve :—Taken over by the Department from the Togoland Mandate Government in 1921. Distance from sea 62 miles. Elevation unknown. No records of rainfall extant.

The magnitude of the annual variations in the rainfall of each station is remarkable, and the low rainfall in years of years of drought is noteworthy. The average rainfall on stations is low when compared with figures for other tropical countries which cultivate cacao, and in these particulars the stations may be taken as typical of the whole country.(6)

At each of the major experiment stations of the Department of Agriculture fields of the four varieties of cacao (Amelonado, Ocumare, Cundeamor and Criollo) have been established. At the older stations these fields served as sources of seed to supply the demands of farmers, and in this respect the stations have filled a very definite need in helping to cope with the amazingly rapid spread of the plant over the whole country.

NATURE OF TRIALS.

In subsequent years, records were kept of the yields of the four varieties, and the figures can now be used to gain some idea of the relative value of the four varieties.

In addition, the figures are useful as indications of the probable yields of cacao in different parts of the country, and this is especially valuable because it is not possible to obtain accurate records of yields from the occupiers of farms. Incorrect statements or estimates of yields per acre are common and current, and the publication of results obtained at experiment stations should go far to supplying a basis for more exact and reasonable knowledge.

There have been no systematic trials of the effects of manures, or of different methods of cultivation or pruning. The fields have been given ordinary attention such as cleaning, pruning of dead branches, removal of diseased pods, burial of shells, and, in some cases mulching with organic material. Results are therefore probably comparable with the better types of farmer's fields of the Colony.

In general the chief value of the records published here is statistical. There exist no accurate agricultural statistics of yields and areas of cacao in the country, there is no exact knowledge of the most ordinary facts concerning this crop, and there has been no means, in the past, of making even approximate forecasts of the dimensions of the annual crop of cacao. The figures published in this Bulletin should provide a basis of sound knowledge on which a system of statistical

publications may be based. The need for exact forecast is of special urgency in the Gold Coast where the whole crop is bought locally by dealers, sent from Europe for the purpose, to whom exact knowledge is of the most vital importance.

It is not possible to deal with the whole question in one Bulletin. A separate Bulletin is being planned in which an endeavour will be made to trace some correlation between distribution and amount of rainfall and magnitude of the resulting crop, while another will deal with the individual variations of yields of cacao trees. Later, it will be possible to publish figures shewing the effects of different manures, a question which has been entirely neglected in the past, both by the Department of Agriculture and by local farmers.

The present Bulletin can provide reasonably accurate information on the following points :—.

(a) Comparative yields of different varieties.
(b) Yields per acre in different parts of the country.
(c) Monthly distribution of crop in different districts.
(d) Annual fluctuation of yields.
(e) Annual variations in size of pods.
(f) Length of vigorous life of the cacao plant under local conditions.

Tables giving the monthly yields per acre of the different varieties at each experiment station, the basis of the summaries in the list are reproduced at the end of this Bulletin, and may be consulted by readers who wish to study the results in detail. The results are given in numbers of marketable pods per acre, both because records have been kept in this form and because this figure is more intelligible and probably more exact than are figures of weights of cured cacao. In each case the ratio of pods per pound of dry cured cacao is given for the year's work.

It is clear that these figures are not complete records of the yielding capacity of the trees, but are merely records of the amount of cacao produced and manufactured. Pods which practically reached maturity and then died from disease or unfavourable climatic conditions are not included, and the loss due to these causes varied from 3 to 20 per cent at various stations. The tables published herein are therefore comparable with crop returns which would be recorded by estates run on commercial lines.

(a) and (b) *Comparative yields of varieties* and in different parts of the country.

Summary *A*. gives the yields in lbs per acre of cured cacao for the different varieties at the various stations.

SUMMARY A.

Pounds of Cured Cacao per Acre.

Stations.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.	
						Amelonado.											
Aburi	1,038	1,275	1,331	1,051	724	1,102	1,627	1,103	862	574	629	716	746	799	738	954	
Asuansi (IV) ..								1,584	1,020	907	970	766	799	828	607	935	
,, (V) ..								874	738	367	886	538	503	564	413	610	
Kibi					68	397	688	662	835	865	970	350	468	725	557	617	
Kpeve												456	616	219	581	486	595
Kumasi									599	610	564	503	437	525	480	532	
Peki-Blengo (II)			250	331	501	490	557	842	576	530	318	577	617	909	316	524	
,, ,, (III)			169	158	292	445	315	775	810	447	225	326	364	120	303	357	
Wiawso											389	217	629	160	312	343	
						Ocumare.											
Aburi				162	202	313	356	370	249	342	353	399	489	710	273	351	
Asuansi								658	446	663	763	598	692	479	372	584	
Kibi				20	140	276	387	440	476	307	427	275	53	281	265	279	
Kumasi										386	466	516	621	499	583	502	409
Peki-Blengo ..							47	329	336	300	229	341	379	271	210	271	
Wiawso											619	315	766	182	450	466	

SUMMARY A.—(*contd.*

POUNDS OF CURED CACAO PER ACRE.

Stations	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.	
						CUNDE	AMOR.										
Aburi		72	200	217	155	160	235	258	217	134	69	167	163	152	139	180	332
Asuansi								591	441	401	624	484	390	505	237	459	
Kibi					63	99	200	295	304	590	493	342	458	325	338	319	
Kumasi										498	425	646	518	450	500	511	
Peki-Blengo ..							13	211	218	240	101	141	179	57	143	145	
Wiawso											515	303	725	249	433	381	
						CRIOL	LO.										
Aburi					58	161	255	358	468	254	292	462	340	450	334	312	238
Asuansi (A) ..								205	182	62	169	281	166	208	171	180	
,, (B) ..								174	118	119	197	139	100	111	104	133	
Kibi					23	108	213	199	374	378	444	357	331	221	192	258	
Kumasi										348	515	231	277	237	241	307	

It will be seen that the Criollo type has given uniformly poor results at all stations and must therefore be considered unsuited to the condition of soil, climate and treatment which obtain on the Gold Coast.

At Aburi, Kibi, and Peki, the results of Amelonado are far ahead of either Ocumare or Cundeamor, at Asuansi and Kumasi, the results with Ocumare and Cundeamor closely approach those of Amelonado while at Wiawso the yields of the last two are superior to the yield from Amelonado.

Aburi differs from all other stations in its high elevation.

The stations Kibi and Peki cannot be considered to be very good cacao land. Asuansi and Kumasi and Wiawso are fair. These results suggest that Cundeamor and Ocumare are likely to do well only in the better land, where the results will approach and may beat those of Amelonado but the latter will be the most successful on the poorer areas and in the higher elevation is therefore the one to be generally used.

(c) *Monthly Distribution of Crop.*

The average percentage distribution of the crop month by month is given for all stations and all varieties in Table I., at the end of this Bulletin. It will be noticed that, in general, the year is divided into a major fruiting season of five months (September to January), and a minor season ('mid-crop', May and June). In the former from 70 to 95 percent of the year's total of fruit is produced, while the 'mid crop' accounts for 5 to 30 per cent of the annual total.

The distribution varies very considerably from year to year on any one station, as may be seen from observation of the tables of annual yields given at the end of this Bulletin. When the mean distribution over a lengthy term of years is considered, however, it is found that there is very little difference between the fruiting season on different stations or of different varieties. In general, the monthly distribution of the crop is practically the same for all varieties and for all parts of the country.

SUMMARY B.

Monthly percentage Distribution of Cacao Crop.

Months.	Season	Varietal.				Geographical.							
		Amelonado 8 Stations 96 Years.	Ocumare. 6 Stations 52 Years.	Cundeamor. 6 Stations 55 Years.	Criollo. 4 Stations 52 Years.	Aburi. 4 Varieties 54 Years.	Asuanti. 4 Varieties 73 Years.	Kibi. 4 Varieties. 39 Years.	Kpeve. 1 Variety 4 Years.	Kumasi. 4 Varieties 25 Years.	Peki Blengo. 3 Varieties 40 Years.	Tarkwa. 1 Variety 5 Years.	Wiawso. 3 Varieties 15 Years.
March		.8	.6	.5	.8	.4	1.1	.2	4.3	.0	.8	.0	1.1
April		2.8	2.4	2.5	3.6	4.4	3.3	.8	5.2	.0	3.3	1.5	3.0
May	Mid ..	4.4	4.6	4.5	6.9	6.8	6.3	1.6	6.7	1.0	6.2	3.6	3.9
June	Crop ..	2.7	2.8	3.4	4.5	4.4	4.7	1.4	2.4	.9	1.4	0.6	4.1
July		1.5	1.1	1.0	1.5	1.5	1.8	.2	.0	.5	2.0	7.8	.7
August		1.9	1.0	.9	1.5	2.1	1.7	.4	.9	1.5	1.1	3.0	.5
September		9.7	4.5	3.9	4.5	7.6	4.7	5.5	5.9	12.6	3.4	25.3	3.3
October	Main ..	19.7	15.1	11.8	15.7	11.9	16.6	23.4	15.8	22.8	11.6	27.5	10.[illegible]
November	Crop ..	28.1	25.2	25.8	25.7	21.1	29.1	33.6	23.9	28.6	24.5	21.4	22.1
December		19.0	24.6	26.3	22.5	22.9	22.1	24.2	16.0	17.1	25.7	19.1	22.2
January		7.9	15.6	16.1	10.0	13.7	7.0	7.8	9.3	12.0	18.5	.7	21.6
February		1.5	2.8	3.3	2.7	3.2	1.6	.9	9.6	3.0	1.5	.5	6.9
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

For convenience of observation, the mean percentage distribution of each variety and of each station, are given in the following Summary B. The average distribution of the crop of the four varieties is practically the same, and is irrespective of the geographical situation of the stations. We find, however, that Kpeve, and to a less extent, Peki-Blengo, Tarkwa and Wiawso, differ from the other stations. At Kpeve there is practically one crop, extending from September to June, while the other three stations shew minor differences of distribution of their mid crop.

It seems clear that the distributions of the crop is governed chiefly by the distribution of the annual rainfall, and that the differences in composition of soil and in other factors are of comparatively minor importance.

If we examine the tables showing the monthly distribution year by year, for these stations a decrease in the mid-season crop will be noticed which is so pronounced for Kibi and Peki as to suggest that under the less suitable conditions, with the increasing age of the tree, the mid-season crop tends to disappear.

It is suggested that the two fruiting-seasons of cacao in the Gold Coast are the result of the two rainfall seasons of the country. A period of four to six months elapses between the emergence of a cacao flower and the maturity of the resultant pod, and thus it is probable that the mid crop is dependent on the minor rainy season, and the major crop on the major rainy season.

In Summary C. the distribution of crop and rainfall are given side by side for each station the figures of crop-yields having been set forward six months relatively to the rainfall figures.

It will be noted that there is a close parallelism between the two sets of figures in the case of each station. It seems clear that the parallelism must be a question of cause and effect.

One of the most difficult problems in agricultural statistical work is the establishment of the correlation between rainfall and crop. It is obvious that, within definite limits and when other factors remain constant, any crop must be intimately dependent upon the rainfall. It is very rarely possible to prove the relationship with a degree of exactness great enough to provide a basis for sure prophecy. The total amount of rainfall, the method of distribution of the rainfall, the inherent flowering and fruiting habits of the plant, the atmospheric

SUMMARY C.

Distribution of Rainfall and Cacao Crop.

Months.			Aburi		Asuansi		Kibi		Kumasi		Peki Blengo		Tarkwa		Wiawso	
Crop	Rain	Season	Crop 54 yrs.	Rain	Crop 58 yrs.	Rain	Crop 39 yrs.	Rain	Crop 25 yrs.	Rain	Crop	Rain	Crop	Rain	Crop	Rain
March ..	September		.4	7.3	1.1	6.3	.2	9.1	.0	12.4	.8	12.6	.0	6.3	1.1	9.5
April ..	October ..	Minor	4.4	11.8	3.3	9.4	.8	13.0	.0	13.4	3.3	12.2	1.5	12.2	3.0	12.6
May ..	November	Rains and Crop	6.8	9.9	6.3	6.9	1.6	9.6	1.0	6.8	6.2	7.4	3.6	9.6	3.9	8.1
June ..	December		4.4	4.3	4.7	4.9	1.4	4.7	.9	2.2	1.4	2.8	6.6	4.9	4.1	2.9
July ..	January ..		1.5	2.3	1.8	3.2	.2	1.9	.5	1.0	2.0	1.4	7.8	2.8	.7	2.4
August ..	February		2.1	4.6	1.7	5.5	.4	4.8	1.5	4.0	1.1	3.7	3.0	5.0	.5	3.8
September	March ..		7.6	7.9	4.7	7.7	5.5	9.1	12.6	8.7	3.4	7.6	25.3	8.7	3.3	10.5
October ..	April ..	Major Rains	11.9	11.2	16.6	11.3	23.4	11.1	22.8	10.5	11.6	10.5	27.5	10.7	10.6	9.2
November ..	May ..	and Crop.	21.1	12.9	29.1	14.3	33.6	9.9	28.6	11.2	24.5	8.7	21.4	12.9	22.1	12.4
December ..	June ..		22.9	15.4	22.1	16.8	24.2	14.6	17.1	15.0	25.7	17.8	19.1	15.4	22.2	16.5
January ..	July ..		13.7	7.8	7.0	8.5	7.8	7.4	12.0	9.4	18.5	9.0	.7	8.5	21.6	8.5
February ..	August ..		3.2	4.6	1.6	5.2	.9	4.8	3.0	5.4	1.5	6.3	.5	3.0	6.9	3.6
Total ..			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

temperature, the force of the wind, the amount of sunshine, the incidence of pest attack, are all variable factors, and the distribution and amount of the crop are the resultant of any or of all of these. Some evidence of the effects of rainfall on cacao yields offered, by Mr. T. J. S. Smellie, Assistant Superintendent of Agriculture in the Journal of the Agricultural Society.(7)

It is not possible here to go further into the question of correlation of rainfall and crop. Differences which occur annually in the distribution of the rainfall are no doubt the main causes of variations in the distribution of the crop, and a close and lengthy study is necessary, directed towards solving the many and intricate problems of causes and effects. It is possible that the daily distribution of rainfall during the critical periods of emergence of the flowers and of setting of the young fruit may have to be studied before any safe conclusions can be drawn.

(d) *Annual fluctuation in the yield.*

The summary (A) shows the variation year by year in the crops at the various stations; apart from the effects of the rainfall, which is certain to be the chief factor, the age of the plants seems to have a noticeable effect. At Aburi, Asuansi the earlier Amelonado crops were very heavy and show a gradual falling off to a somewhat constant level.

There is evidence of the same condition in the case of most of the other stations—but less pronounced.

The alterations of fair and poor crops succeeding one another, to be seen at some of the stations, particularly in the more recent years, or a particularly good crop being followed by a comparatively poor one, is very striking.

(e) *The variation in the size of pods.*—Summary (D) shows the variation year by year of size of pods for the different stations for varieties.

The causes this variation cannot yet be determined. It will be seen that the pods may be large or small for the different varieties on a particular station in a particular year, and the largest or smallest pods of any one variety occur in widely scattered years for the different stations.

Nor is there any regularity in the increase or decrease in the size of the pod with the increasing age of the tree nor is there any readily apparent connection between the size of the pod and the total crop.

SUMMARY D.

Number of Pods per lb, Cured Cacao.

Stations.	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
							Amelonado.									
Aburi	13.1	16.1	11.1	13.1	14.5	15.1	13.9	13.5	14.4	14.5	14.1	18.8	[illegible]	[illegible]	14.2	14.0
Asuansi	—	—	—	—	—	—	—	—	12.1	13.8	8.0	13.8	[illegible]	[illegible]	[illegible]	11.4
„	—	—	—	—	—	—	—	—	10.9	13.0	10.6	13.7	12.8	12.1	12.0	11.1
Kibi	—	—	—	—	20.0	22.7	13.4	12.2	[illegible]	14.0	13.0	12.2	14.1	[illegible]	[illegible]	18.9
Kpeve	—	—	—	—	—	—	—	—	—	—	—		9.3	8.7	17.9	14.1
Kumasi	—	—	—	—	—	—	—	—	—	12.5	12.8	13.2	[illegible]	[illegible]	[illegible]	14.3
Wiawso	—	—	—	—	—	—	—	—	—		—	11.9	[illegible]	[illegible]	[illegible]	14.8
							Cundeamor.									
Aburi	—	—	10.7	11.1	12.0	11.9	11.9	10.4	10.2	11.0	11.1	[illegible]	10.0	9.3	10.4	10.2
Asuansi	—	—	—	—	—	—	—	—	11.5	11.4	11.5	12.1	[illegible]	[illegible]	10.0	11.3
Kibi	—	—	—	—	12.5	12.7	11.4	11.8	12.0	13.7	11.7	[illegible]	11.7	[illegible]	[illegible]	11.1
Kumasi	—	—	—	—	—	—	—	—	—		11.5	[illegible]	[illegible]	[illegible]	13.0	11.9
Peki	—	—	—	—	—	—	—	15.9	12.2	[illegible]	12.3	[illegible]	[illegible]	[illegible]	21.0	11.2
Wiawso	—	—	—	—	—	—	—	—	—	—	—	11.9	12.0	[illegible]	14.6	14.8
							Ocumare.									
Aburi	—	—	—	—	15.1	13.8	7.8	13.2	10.4	15.7	13.0	12.0	14.0	[illegible]	[illegible]	14.5
Asuansi	—	—	—	—	—	—	—	—	10.2	12.4	9.9	12.4	11.6	10.7	11.0	10.0
Kibi	—	—	—	—	12.2	12.7	12.4	11.4	12.0	11.7	13.7	11.4	13.5	10.9	[illegible]	12.1
Kumasi	—	—	—	—	—	—	—	—	—	—	12.1	11.5	11.9	14.5	11.7	12.1
Peki	—	—	—	—	—	—	—	11.1	11.2	8.4	10.6	10.7	11.0	11.1	11.1	11.4
Wiawso	—	—	—	—	—	—	—	—	—	—	—	11.2	12.5	12.9	14.3	12.8
							Criollo.									
Aburi	—	—	—	—	—	19.5	13.7	16.9	14.2	15.5	10.0	13.4	8.6	11.1	12.5	13.5
Asuansi	—	—	—	—	—	—	—	—	12.8	11.5	13.1	14.3	13.0	13.5	13.0	11.8
„	—	—	—	—	—	—	—	—	12.8	11.5	13.1	14.3	13.0	13.5	11.0	14.2
Kibi	—	—	—	—	12.0	12.0	17.8	12.8	11.8	14.0	11.5	11.6	12.0	11.1	11.3	11.7
Kumasi	—	—	—	—	—	—	—	—	—	—	12.4	12.3	16.4	14.4	12.5	13.8

The effect of removing some of the fruit from a plant in which size is important to encourage the development of the remainder is well known and it may be that the cacao plant with an amount of material available for a crop, will produce that crop independently of the actual number of pods it may be spread over—in which case the actual number is not an important matter, except in so far as it affects the amount of labour involved in the working up of the crop —which under the condition here is a point of negligible importance.

(f) *Length of life of the cacao plant.*

Numerous cases have occurred of plantations of cacao dying completely out. All these however, appear to have been due to unsuitable conditions combined with want of attention. In the Stations of the Department the results of Amelonado cacao, at Tarkwa were so poor as to cause the plot to be abandoned, while at Peki one Amelonado plot failed to be established and at Juaso (a small station recently discontinued to be worked as a station) the Amelonado cacao was a failure. At all these however, it was unsuitable condition which caused the trees to die out or fail. At some of the stations have any trees ceased to bear on account of age, nor has any instance been met with in the country of Cacao plants having reached their age limit.

There is a general idea that cacao plants in the Gold Coast will not live to the ages which obtain in other countries but there is at present nothing which can be accepted as evidence to support the contention.

On suitable land it appears that the trees bear their heaviest for a few years after maturing and then the crop appears to fall off to a lower level where it is likely to remain stationary and provided the necessary attention is given—which will doubtless include the addition to the soil of some form of plant food—there would appear to be no reason to consider the cacao plant in the Gold Coast compared with it in other countries a particularly short lived tree.

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(4) " Cocoa," by C. J. J. Van Hall,

Macmillan and Company Limited, 1914.

(5) Cacao, by J. H. Hart, 1911.

(6) Rainfall of the Gold Coast, by G. G. Auchinleck, M.Sc., F.I.C., Bulletin 2 of Dept., of Agriculture, Gold Coast, 1926.

(7) Journal of the Gold Coast Agricultural and Commercial Society, January-March, 1924. T. J. S. Smellie, Assistant Superintendent of Agriculture.

TABLE I.

MONTHLY PERCENTAGE DISTRIBUTION OF CACAO CROPS.

		Amelonado Variety.										Ocumare Variety.			
		Aburi (16 years)	Asuansi Plot IV (15 years)	Asuansi Plot V (11 years)	Kibi (11 years).	Kpevi 4 (Years).	Kumasi. (7 years).	Peki-Blengo II (11 years).	Peki-Blengo III (11 years).	Tarkwa (5 years).	Wiawso (5 years).	Aburi (12 years).	Asuansi (10 years).	Kibi (10 years).	Kumasi (6 years).
March		.1	1.1	.7	.1	4.3	.0	1.2	1.1	.0	.8	.1	1.4	.3	.0
April		2.0	3.1	2.0	1.0	5.2	.0	5.0	5.3	1.5	2.8	4.2	3.3	.9	.0
May	Mid crop	3.0	6.5	3.6	1.7	6.7	1.1	7.8	6.1	3.6	3.8	7.7	4.9	1.6	.5
June	Mid crop	1.8	5.2	3.8	1.2	2.4	1.0	1.5	1.0	6.6	3.5	3.8	3.7	1.5	.6
July		1.1	2.6	1.1	.3	.0	.1	1.5	1.1	7.8	.8	1.3	1.1	.3	1.6
August		3.4	1.8	1.8	.5	.9	2.9	1.9	1.6	3.0	.7	1.1	1.8	.6	1.2
September	Main crop	18.4	5.0	6.1	8.3	5.9	20.5	3.3	3.1	25.3	4.1	3.0	3.5	4.6	11.6
October	Main crop	21.1	17.1	23.5	24.3	15.8	34.2	14.2	11.4	27.5	12.5	7.7	12.4	26.9	21.3
November	Main crop	22.6	32.5	34.3	36.8	23.9	23.4	28.2	27.1	21.4	29.0	18.6	26.7	33.3	30.5
December	Main crop	20.2	19.1	18.5	21.0	16.0	10.2	21.1	23.1	19.1	18.1	24.6	28.9	22.4	14.4
January	Main crop	5.7	5.2	3.6	4.6	9.3	5.7	10.8	17.0	.7	19.1	22.4	10.7	6.7	16.0
February		.6	.8	1.0	.2	9.6	.9	1.5	2.1	.5	4.8	5.5	1.6	.9	2.3
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE I—(*contd.*)

MONTHLY PERCENTAGE DISTRIBUTION OF CACAO CROPS.

		OCUMARE (*contd.*)		CUNDEAMOR VARIETY.						CRIOLLO VARIETY.				
		Peki-Blengo (9 years).	Wiawso (5 years.)	Aburi (14 years).	Asuansi (13 years).	Kibi (8 years).	Kumasi (6 years).	Peki-Blengo (9 years).	Wiawso (5 years).	Aburi (12 years).	Asuansi Plot A (12 years).	Asuansi Plot B (12 years).	Kibi (10 years).	Kumasi (6 years).
March		.6	1.3	.7	1.0	.0	.0	.0	1.1	1.0	1.4	1.0	.3	.0
April		1.5	3.6	5.0	3.5	.1	.0	.8	2.7	6.9	3.5	4.4	.9	.0
May	Mid crop	6.3	4.6	6.8	6.1	1.2	1.3	4.5	3.4	11.1	7.9	8.6	1.9	1.3
June	Mid crop	2.1	4.4	5.7	4.7	1.2	1.1	1.2	4.3	6.[illegible]	5.8	4.7	1.8	1.0
July		1.4	.6	1.8	1.5	.0	.3	.3	.8	2.0	2.3	1.8	.3	.1
August		.7	.2	1.6	1.4	.0	1.3	.0	.5	1.9	2.4	1.4	.6	.3
September	Main crop	4.0	2.7	2.9	4.4	4.8	8.9	1.0	3.0	3.2	5.5	3.8	4.6	8.1
October	Main crop	13.2	10.4	8.7	14.2	18.0	14.9	7.5	8.9	7.0	13.9	18.1	23.3	18.4
November	Main crop	21.8	19.7	22.4	24.5	35.4	38.8	20.3	17.8	20.1	24.3	30.9	29 7	22.7
December	Main crop	28.0	26.3	25.9	26.3	26.9	18.5	33.1	22.1	21.1	23.5	16.9	27.4	26.5
January	Main crop	19.9	19.1	13.7	10.6	11.2	11.2	29.4	26.6	15.6	6.4	6.5	7.9	16.2
February		.5	7.1	4.8	1.8	1.2	3.7	1.9	8.8	2.6	3.1	1.9	1.3	5.4
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 2.

ABURI EXPERIMENT STATION.—EASTERN PROVINCE:

YIELDS OF CACAO PER ACRE.

Varvity of Cacao	Amelonado
Area of field	3.23 acres
Planting Distance	15'x1 .'
Date of Planting	1891–1893

	Number of pods per acre.																
	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean
January ..	—	2,898	335	—	183	138	129	318	—	405	228	190	1,479	8,526	437	15,146	1,901
February	456	45	—	273	53	—	—	26	64	10	—	—	—	1.432	34	634	189
March ..	190	—	—	486	12	8	—	58	12	—	28	—	—	—	—	—	49
April ..	294	148	157	597	24	345	107	68	—	673	—	5	—	6,057	615	1,349	652
May ..	153	151	930	707	126	648	—	156	40	440	313	222	—	6,349	5,388	—	976
June ..	159	176	413	90	194	403	675	142	189	—	—	156	180	3,739	—	2,150	585
July ..	—	105	789	24	213	—	477	947	495	113	72	—	—	380	—	2,166	361
August ..	—	—	1,496	1,611	1,092	565	173	1,260	792	295	—	—	198	5,190	5,513	—	1,136
September	1,285	156	951	2,615	1,370	1,660	4,495	3,973	3,369	2,233	589	459	629	18,984	19,805	20,178	6,109
October ..	2,414	4,510	1,173	5,178	5,350	1,650	3,773	2,924	5,867	4,446	2,140	—	1,266	31,500	9,617	31,174	6,980
November	4,168	6,236	5,984	3,991	3,362	3,443	2,911	1,348	2,493	1,687	2,620	2,567	3,059	17,784	44,467	13,816	7,496
December	2,895	2,282	1,915	1,873	3,205	2,075	2,586	10,260	2,574	2,294	2,040	9,226	4,652	16,894	27,569	16,777	6,698
Totals ..	12,014	16,717	14,143	17,445	15,244	10,935	15,326	21,970	15,895	12,596	8,030	12,825	11,463	117,835	113145	103390	33,132
Pods per lb of cured cacao	**13.1**	**16.1**	**11.1**	**13.1**	**14.5**	**15.1**	**13.9**	**13.5**	**14.4**	**14.5**	**14.1**	**18.8**	**16.0**	**15.8**	**14.2**	**14.0**	
Pounds of cured cacao per acre.	**917**	**1,038**	**1,275**	**1,331**	**1,051**	**724**	**1,102**	**1,627**	**1,103**	**862**	**574**	**629**	**716**	**746**	**799**	**738**	

TABLE 3.

ABURI EXPERIMENT STATION.—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	**Cundeamor**
Area of field	2.4 acres
Planting Distance	15′x15′
Date of Planting	1906.

	Number of Pods per acre.														
	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean
January	7	—	8	—	40	352	—	527	321	384	913	497	335	464	275
February	1	258	245	38	—	273	116	122	—	—	—	60	50	253	97
March	—	2	48	—	—	60	39	—	46	—	—	—	—	—	14
April	7	254	142	166	92	92	—	409	—	—	—	64	19	161	100
May	141	154	103	399	—	144	85	262	94	27	—	295	230	—	138
June	60	22	77	360	356	98	95	1	—	73	121	156	—	192	115
July	17	—	30	—	144	40	129	84	9	—	—	—	—	76	37
August	24	4	64	8	18	154	108	16	—	—	23	28	33	—	34
September	14	120	123	74	156	105	97	26	7	27	29	31	12	—	59
October	36	322	285	126	292	140	644	119	153	—	81	73	105	74	175
November	133	551	597	143	546	415	662	327	346	33	124	119	302	111	444
December	332	532	877	537	625	576	652	499	510	218	274	192	505	82	515
Totals	772	2,219	2,599	1,851	2,269	2,449	2,627	2,392	1,486	762	1,665	1,515	1,591	1,413	2,003
Pods per lb. of cured cacao.	**10.7**	**11.1**	**12.0**	**11.9**	**11.9**	**10.4**	**10.2**	**11.0**	**11.1**	**11.1**	**10.0**	**9.3**	**10.4**	**10.2**	
Pounds of cured cacao per acre.	**72**	**200**	**217**	**155**	**160**	**235**	**258**	**217**	**134**	**69**	**167**	**163**	**152**	**139**	

TABLE 4.

ABURI EXPERIMENT STATION:—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao .. .. Ocumare.
Area of field .. .. .19 Acre.
Planting Distance .. .. 12′ x 12′
Date of Planting .. .. 1905.

	Number of Pods per Acre.												
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean
January	120	—	55	605	—	800	795	910	3,025	1,490	1,765	1,710	**938**
February	160	—	—	280	445	20	—	—	—	1,580	55	255	**233**
March	10	—	—	—	—	—	60	—	—	—	—	—	**6**
April	390	310	295	—	—	485	—	—	—	300	95	235	**176**
May	25	785	—	335	—	295	180	360	—	575	1,340	—	**324**
June	190	330	420	—	40	—	—	80	395	230	—	225	**159**
July	50	35	100	—	85	300	55	—	—	—	—	25	**54**
August	—	—	—	105	—	20	—	—	210	65	140	—	**45**
September	40	—	145	180	95	35	145	125	30	105	765	—	**128**
October	305	—	365	255	1,015	90	1,015	—	50	225	420	140	**323**
November	580	200	455	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	655	**783**
December	580	970	[illegible]	1,945	[illegible]	[illegible]	575	[illegible]	[illegible]	[illegible]	[illegible]	720	**1,032**
Total	2,450	2,790	2,435	4,695	3,850	3,930	4,645	4,230	5,585	5,450	7,950	3,965	4,201
	2,558			4,155			4,820			5,788			
Pods per lb of Cured Cacao	**15.1**	**13.8**	**7.8**	**13.2**	**10.4**	**15.7**	**13.6**	**12.0**	**14.0**	**11.2**	**11.2**	**14.5**	
Pounds of Cured Cacao per Acre.	162	202	313	356	370	249	342	353	399	489	710	373	**351**

TABLE 5.

ABURI EXPERIMENT STATION:—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao Criollo.
Acre of Field .52 acre.
Planting Distance 12′ x 12′
Date of Planting 1909.

	Number of Pods per acre.												
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January	28	—	60	462	—	688	1,056	—	1,658	610	734	1,726	**585**
February	36	—	—	208	272	116	—	64	—	178	132	142	**96**
March	20	56	16	90	20	—	240	—	—	—	—	—	**37**
April	—	—	30	320	—	1,892	—	14	—	434	192	232	**259**
May	50	344	430	336	82	984	578	266	—	700	1,208	—	**415**
June	22	80	178	254	84	—	—	380	568	552	—	976	**258**
July	—	—	144	110	144	364	60	—	—	—	—	94	**76**
August	—	—	134	74	110	74	—	—	64	104	294	—	**71**
September	—	—	354	78	396	138	72	54	56	96	180	42	**122**
October	102	94	—	208	1,282	286	956	—	78	100	194	126	**285**
November	—	150	412	556	1,234	842	936	2,556	488	182	1,274	434	**755**
December	—	410	454	1,608	1,462	1,892	414	574	1,060	834	153	634	**792**
Total	**258**	**1,134**	**2,212**	**4,304**	**5,086**	**7,276**	**4,312**	**3,974**	**3,912**	**3,790**	**5,664**	**4,406**	**3,751**
		1,201			**5,555**			**4,066**			**4,620**		
Pods per lb. of cured Cacao	—	**19.5**	**13.7**	**16.9**	**14.2**	**15.5**	**16.9**	**13.4**	**8.6**	**11.1**	**12.5**	**13.5**	
Pounds of Cured Cacao per acre ..	—	**58**	**161**	**255**	**358**	**468**	**254**	**292**	**462**	**340**	**450**	**334**	**312**

TABLE 6.

ASUANSI EXPERIMENT STATION CENTRAL PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of cacao	Amelonado (Plot V)
Area of field	2 acres
Planting Distance	10'x10'
Date of Planting	1912–1915.

	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean.
January ...	—	128	185	739	519	—	140	207	250	300	358	257
February ...	—	25	55	—	—	420	—	89	33	17	142	71
March ...	—	87	—	—	50	—	200	93	75	66	17	53
April ...	—	—	68	268	587	—	163	105	94	204	56	140
May ...	30	369	254	328	748	—	325	133	355	236	56	258
June ...	5	751	300	261	513	452	33	210	113	239	53	266
July ...	—	186	—	—	153	—	28	230	23	197	22	76
August ...	—	—	126	315	284	68	33	202	45	272	34	125
September ...	—	—	384	1,141	753	402	322	593	401	520	203	429
October ...	224	491	428	[illegible]	1,545	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,545	1,660
November ...	—	1,642	3,449	1,975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,423
December ...	683	2,689	2,700	[illegible]	1,455	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,306
Totals ...	942	6,368	7,940	10,576	10,187	3,268	11,344	8,999	6,389	6,774	4,919	7,064
	—	—		9,568			7,870			6,024		—
Pods per lb. of cured cacao.	—	—	—	12.1	13.8	8.9	13.8	16.7	12.7	12.0	11.4	—
Pounds of cured cacao per acre.	—	—	—	874	738	367	886	538	503	564	413	610

TABLE 7.

ASUANSI EXPERIMENT STATION:—CENTRAL PROVINCE.

YIELDS OF CAÇAO PER ACRE.

Variety of Cacao	Ocumare
Area of field	1.25 acres
Planting Distance	15'x9'
Date of Planting	1910–1917.

Number of pods per acre.

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean 1916–25
January	—	—	—	176	108	1,000	520	1,788	259	576	561	356	668	462
February	—	—	—	56	43	—	—	—	—	142	385	68	182	67
March	—	—	4	92	—	—	211	—	69	192	120	20	47	60
April	—	—	—	—	199	369	683	—	142	148	99	138	80	144
May	—	2	74	288	213	416	448	—	584	276	110	190	133	210
June	—	—	35	353	45	56	220	428	98	369	152	228	55	157
July	—	—	—	99	—	—	96	—	40	132	64	125	39	46
August	—	1	—	—	46	52	187	47	75	74	43	342	114	75
September	—	20	—	—	30	131	116	110	405	161	280	492	203	151
October	5	48	115	123	50	711	360	1,383	1,030	423	1,195	819	676	534
November	5	202	19	644	560	1,286	1,464	1,520	4,032	1,260	1,668	1,166	1,078	1,147
December	14	221	339	738	1,000	2,700	1,224	1,280	2,691	3,006	624	1,328	438	1,246
Totals	24	494	586	2,569	2,294	6,721	5,529	6,565	9,455	6,759	7,407	5,272	3,719	4,299
				1,816			6,272			7,874		4,496		
Pods per lb. of cured cacao.	—	—	—	—	—	10.2	12.4	9.9	12.4	11.3	10.7	11.0	10.0	—
Pounds of cured cacao per acre	—	—	—	—	—	658	446	663	763	598	692	479	372	584

TABLE 8.

ASUANSI EXPERIMENT STATION.—CENTRAL PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Cundeamor.
Area of Field	2 acres.
Planting Distance	15′ x 9′
Date of Planting	1910–1917.

	Number of pods per acre.													
	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January ..	14	330	—	611	457	1,278	551	965	205	364	262	289	460	**460**
February ..	—	—	—	155	104	—	—	—	—	294	248	81	121	**77**
March ..	—	53	34	116	—	—	139	—	60	81	50	11	41	**45**
April ..	4	46	—	—	170	337	718	—	118	81	69	90	69	**154**
May	—	25	90	550	207	446	460	518	545	56	312	148	78	**264**
June	3	7	52	681	125	181	453	67	198	276	259	216	110	**203**
July	—	—	—	209	—	—	192	—	28	230	40	120	22	**65**
August ..	—	40	—	—	35	153	42	—	98	133	41	205	32	**60**
September ..	12	106	—	—	66	273	80	190	695	305	200	360	138	**191**
October ..	70	395	553	250	124	1,144	390	944	1,245	443	836	934	653	**615**
November ..	260	1,195	63	1,032	900	1,084	1,200	1,212	2,722	1,010	1,230	1,010	817	**1,061**
December ..	17	474	1,055	2,445	1,888	1,906	1,150	720	1,665	1,949	564	541	434	**1,139**
Totals ..	380	2,671	1,847	6,049	4,076	6,802	5,034	4,616	7,579	5,222	4,171	5,005	2,775	4,334
		2,737				5,304			5,806			3,984		
Pods per lb. of Cured Cacao	—	—	—	—	—	11.5	11.4	11.5	12.1	10.8	10.7	10.0	11.3	
Pounds of Cured Cacao per acre	—	—	—	—	—	591	441	401	624	484	390	505	237	459

TABLE 9.

ASUANSI EXPERIMENT STATION. CENTRAL PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Criollo (Plot A.)
Area of Field	2.5 acres.
Planting Distance	15′ x 9.′
Date of Planting	1910–1921.

	Number of Pods per acre.												
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January	1	—	97	179	380	215	—	23	222	366	132	306	**112**
February	—	—	24	40	—	—	376	—	113	38	16	98	**54**
March	14	3	20	—	—	68	—	12	141	28	8	14	**24**
April	24	—	—	82	188	80	—	26	88	56	85	24	**60**
May	2	2	60	96	278	317	—	224	154	452	132	66	**137**
June	—	—	138	122	72	256	197	56	188	104	113	66	**101**
July	—	—	27	—	—	63	—	13	236	25	117	36	**40**
August	3	—	—	60	110	74	18	27	103	28	85	30	**41**
September	—	—	—	52	312	118	32	109	146	116	256	98	**95**
October	35	38	107	55	252	313	125	460	216	54	561	461	**243**
November	93	6	242	700	172	88	52	807	1,391	710	634	563	**423**
December	27	57	578	840	856	505	16	668	655	266	565	259	**409**
Totals	**199**	**106**	**1,293**	**2,226**	**2,620**	**2,097**	**816**	**2,425**	**3,653**	**2,243**	**2,704**	**2,021**	**1,739**
		533			**2,314**			**2,298**			**2,323**		
Pods per lb. of Cured Cacao	—	—	—	—	**12.8**	**11.5**	**13.1**	**14.3**	**13.0**	**13.5**	**13.0**	**11.8**	
Pounds of Cured Cacao per acre ...	—	—	—	—	**205**	**182**	**62**	**169**	**281**	**166**	**208**	**171**	**180**

TABLE 10.

ASUANSI EXPERIMENT STATION.—CENTRAL PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Criollo (Plot B.)
Area of Field	2 acres.
Planting Distance	15′ x 9′
Date of Planting	1913–1921.

	Number of Pods per acre.												
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January	10	—	56	62	162	86	—	180	75	189	42	174	**86**
February	—	—	15	7	—	—	151	—	43	13	11	63	**25**
March	3	—	8		—	38	—	30	34	31	9	9	**13**
April	10	—	—	155	57	207	—	100	55	62	17	53	**59**
May	1	1	380	70	132	128	—	93	103	187	109	168	**114**
June	1	3	101	53	42	141	96	15	131	40	68	65	**63**
July	—	—	68	—	—	54	—	20	82	16	36	14	**24**
August	—	—	—	46	28	32	14	3	15	10	74	11	**51**
September	4	—	—	30	68	48	93	30	54	93	151	51	**19**
October	—	30	50	39	1,074	91	294	300	95	407	210	300	**241**
November	12	12	175	155	215	308	449	1,765	981	235	327	316	**412**
December	6	56	263	300	452	226	467	275	150	76	178	256	**225**
Total	**47**	**102**	**1,116**	**917**	**2,230**	**1,359**	**1,564**	**2,811**	**1,818**	**1,359**	**1,232**	**1,480**	**1,332**
		422			**1,502**			**2,064**			**1,357**		
Pods per lb. of Cured Cacao	—	—	—	—	**12.8**	**11.5**	**13.1**	**14.3**	**13.0**	**13.5**	**11.0**	**14.2**	
Pounds of Cured Cacao per acre ..	—	—	—	—	**174**	**118**	**119**	**197**	**139**	**100**	**111**	**104**	**133**

TABLE 11.

ASUANSI EXPERIMENT STATION.—CENTRAL PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado (Plot IV.)
Area of Field	10 acres.
Planting Distance	15′ x 15′
Date of Planting	1908–1911.

Month.	Number of Pods per acre.															
	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January ..	—	—	21	232	—	8[illegible]0	616	2,29[illegible]	1,163	70	361	398	328	229	641	**479**
February ..	—	—	-	—	-	—	188	—	—	510	—	89	180	58	145	**78**
March	—	—	—	133	31	348	—	—	582	—	110	102	90	55	55	**100**
April	1	—	42	259	—	—	750	783	1,443	—	193	71	328	432	95	**289**
May	—	111	10	354	734	8[illegible]2	1,071	1,0[illegible]	1,409	1,090	843	186	679	540	161	**605**
June	5	43	18	192	560	1,063	1,072	440	728	265	150	572	381	1,501	184	**486**
July	8	12	—	43	17	1,363	—	160	352	—	67	788	123	527	120	**239**
August	—	—	17	166	—	—	183	251	202	112	241	235	341	536	202	**170**
September ..	7	—	79	751	—	—	384	1,092	798	884	625	580	598	647	478	**461**
October	16	20	590	2,434	1,524	1,892	661	2,860	2,101	2,184	3,558	588	1,855	1,564	1,797	**1577**
November ..	51	242	1,141	2,640	3,400	6,098	3,912	3,749	3,101	2,920	5,747	4,522	3,817	2,194	1,492	**3,002**
December ..	5	422	530	316	860	4,264	4,980	4,576	2,001	1,583	1,380	1,673	948	1,503	1,372	**1765**
Total ..	**93**	**850**	**2,448**	**7,520**	**7,126**	**16720**	**13817**	**17262**	**13880**	**9,618**	**13275**	**9,804**	**9,668**	**9,942**	**6,742**	**9,251**
		1,130			**10,455**			**14,986**			**10,899**			**8,784**		
Pods per lb. of Cured Cacao,	—	—	—	—	—	—	—	**10.9**	**13.6**	**10.6**	**13.7**	**12.8**	**12.1**	**12.0**	**11.1**	
Pounds of Cured Cacao per acre.	—	—	—	—	—	—	—	**1,584**	**1,020**	**907**	**970**	**?766**	**?799**	**828**	**607**	**935**

TABLE 12

KIBI EXPERIMENT STATION:—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado
Area of field	1.25 Acres
Planting Distance	12′x12′
Date of Planting	1912.

Months.	Number of Pods per acre.												Mean.
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1915-25.
January	—	7	57	148	472	848	551	222	—	393	505	604	**346**
February	—	—	—	22	—	22	—	78	74	—	—	—	**18**
March	—	—	30	77	—	—	—	—	—	—	—	—	**10**
April	—	33	188	170	—	228	203	2	—	150	—	—	**89**
May	—	22	320	137	53	527	98	226	—	163	—	—	**141**
June	—	—	194	306	—	379	74	93	—	32	—	—	**98**
July	—	—	45	140	—	32	—	—	—	—	—	—	**19**
August	—	—	—	334	—	26	70	—	—	—	—	—	**39**
September	—	34	94	372	—	427	2,395	1,061	388	497	913	1,295	**680**
October	—	188	2,043	1,050	3,106	1,344	2,325	4,290	914	1,834	5,798	2,144	**2,355**
November	16	314	1,822	1,877	1,614	4,730	3,761	4,686	4,634	3,698	1,486	5,518	**3,144**
December	—	964	638	3,763	3,100	4,124	1,670	1,175	1,751	2,875	—	970	**1,885**
Totals	16	1,562	5,331	8,396	8,405	12,187	11,247	11,833	7,761	9,642	8,702	10,531	8,824
		2,303			**9,663**			**10,280**			**9,625**		—
Pods per pound cured Cacao.	20	22.7	13.4	12.2	12.7	14.6	13.0	12.2	14.1	20.6	12.0	18.9	—
Pounds of cured cacao per acre.	—	68	397	688	662	835	865	970	550	468	725	557	—

TABLE 13.

KIBI EXPERIMENT STATION:—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Ocumare
Area of Field	1.34 acres
Planting Distance	12′x12′
Date of Planting	1912.

Months.	Number of Pods per Acre.												
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean.
January	—	3	214	121	383	472	245	417	—	256	107	411	219
February	—	—	—	46	—	35	—	4	154	—	—	—	20
March	—	—	35	51	—	—	—	—	—	—	—	—	7
April	—	12	193	72	—	74	36	3	—	8	—	—	33
May	1	127	269	62	—	115	121	71	—	23	—	—	74
June	7	—	185	186	—	54	54	114	—	5	—	—	50
July	—	—	44	70	—	—	—	—	—	—	—	—	9
August	1	—	—	214	—	8	—	—	—	—	—	—	19
September	—	125	36	271	—	60	310	259	193	36	218	417	166
October	43	366	687	1,021	2,085	608	816	1,608	804	141	1,871	951	917
November	59	488	1,467	822	1,407	1,613	1,896	1,694	1,810	40	821	974	1,091
December	134	660	287	1,477	1,407	2,526	607	690	757	70	—	458	756
Totals	245	1,781	3,417	4,413	5,282	5,565	4,085	4,860	3,718	579	3,087	3,211	3,361
		1,814			5,087			4,221			2,292		—
Pods per lb. of cured cacao.	12.2	12.7	12.4	11.4	12.0	11.7	13.3	11.4	13.5	10.9	11.0	12.1	—
Pounds of Cured cacao per Acre.	20	140	276	387	440	476	307	427	275	53	281	265	—

TABLE 14.

KIBI EXPERIMENT STATION:—EASTERN PROVINCE.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Cundeamor
Area of Field	1.25 Acres
Planting Distance	12'x12'
Date of Planting	1912.

Months.?	No. of Pods per Acre.												
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean. 1915–25
January	—	2	138	100	337	459	1,059	456	—	480	392	818	**385**
February	—	—	—	30	—	58	—	198	165	—	—	—	**41**
March	—	—	20	22	—	—	—	2	—	—	—	—	**4**
April	—	20	66	37	—	38	—	2	—	5	—	—	**15**
May	—	—	93	34	—	86	98	100	—	45	—	—	**41**
June	—	—	88	89	—	61	158	166	—	22	—	—	**53**
July	—	—	—	12	—	—	—	—	—	—	—	—	**1**
August	—	—	—	44	—	3	—	—	—	—	—	—	**4**
September	—	35	18	106	—	93	459	211	114	334	258	424	**186**
October	1	74	260	487	784	327	1,082	1,334	393	694	554	588	**598**
November	89	272	491	405	704	1,269	2,807	1,761	2,049	1,658	1,246	1,208	**1,261**
December	31	401	247	994	760	1,771	1,244	1,482	1,280	2,353	1,200	717	**1,041**
Totals	**121**	**804**	**1,421**	2,360	2,585	4,165	6,907	5,713	4,001	5,591	3,650	3,755	3,630
		782			3,037			5,540			4,332		
Pods per lb. cured cacao	12.5	12.7	14.4	11.8	12.0	13.7	11.7	11.6	11.7	12.2	11.8	11.1	—
Pounds of cured Cacao per acre.	1	63	99	200	295	304	590	493	342	458	325	338	—

TABLE 15.

KIBI EXPERIMENT STATION:- EASTERN PROVINCE.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Criollo
Area of Field	·57 acre
Planting Distance	12'x12'
Date of Planting	1912.

Months	Number of Pods per acre.											
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean. 1915–25
January	—	4	23	154	248	420	245	229	—	347	450	679	**254**
February	—	—	—	40	—	40	—	100	257	—	—	—	**40**
March	—	—	21	35	—	—	—	—	—	—	—	—	**5**
April	—	—	70	35	—	72	—	4	—	222	—	—	**37**
May	—	—	133	82	—	186	135	128	—	—	—	—	**60**
June	—	—	107	170	—	79	121	125	—	—	—	—	**55**
July	—	—	18	95	—	11	—	—	—	—	—	—	**11**
August	—	—	—	26	—	54	—	—	—	—	—	—	**7**
September	—	32	30	98	—	135	698	205	110	105	172	98	**153**
October	—	39	691	532	312	588	1,194	475	473	369	1,192	453	**665**
November	16	56	828	—	763	1,500	1,575	1,628	1,995	891	688	688	**965**
December	—	144	—	1,460	1,022	2,146	380	1,253	1,449	1,736	—	329	**903**
Totals	**16**	**275**	**1,921**	**2,727**	**2,345**	**5,231**	**4,348**	**5,147**	**4,284**	**3,670**	**2,502**	**2,247**	**3,154**
					3,434			**4,593**			**2,806**		—
Pods per lb. cured Cacao	12.0	12.0	17.8	12.8	11.8	14.0	11.5	11.6	12.0	11.1	11.3	11.7	—
Pounds of cured Cacao per acre.	**1**	**23**	**108**	**213**	**199**	**374**	**378**	**444**	**357**	**331**	**221**	**192**	—

TABLE 16.

KPEVE EXPERIMENT STATION.—TOGOLAND.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado.
Area of Field	20 acres.
Planting Distance	12½′ x 12½.′
Date of Planting	

	Number of Pods per acre.				
	1922.	1923.	1924.	1925.	Mean.
January	—	804	319	971	**523**
February	—	939	—	1,226	**541**
March	—	356	469	142	**242**
April	440	620	110	—	**292**
May	635	416	472	—	**381**
June	198	102	200	52	**138**
July?	—	—	—	—	**0**
August	142	67	—	—	**52**
September	560	306	—	424	**322**
October	999	905	398	1,265	**892**
November	599	1,120	1,437	2,253	**1,352**
December	669	572	520	1,860	**905**
Total	4,242	5,363	3,926	8,196	5,640
Pods per lb. of Cured Cacao ..	9.3	8.7	17.9	14.1	11.6
Pounds of Cured Cacao per acre ..	**456**	**616**	**219**	**581**	**486**

TABLE 17.

KUMASI EXPERIMENT STATION.—ASHANTI.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado.
Area of Field	11 acres.
Planting Distance	15′ x 15′
Date of Planting	1908–1910

	Number of Pods per acre.							
	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January	322	89	336	1,631	—	—	373	**393**
February	—	—	46	212	—	—	175	**62**
March	—	—	—	—	—	—	—	**0**
April	—	—	—	—	—	—	—	**0**
May	203	—	98	—	220	—	—	**74**
June	87	38	—	128	130	—	127	**73**
July	—	—	37	—	—	—	—	**5**
August	378	—	230	—	—	620	182	**202**
September	978	2,438	1,165	—	1,501	1,927	1,921	**1,418**
October	2,275	1,984	2,074	2,882	3,088	2,124	2,134	**2,366**
November	2,344	2,489	1,677	1,645	1,202	733	1,269	**1,623**
December	917	777	1,220	—	381	951	697	**706**
Total	7,497	7,815	6,883	6,498	6,522	6,355	6,878	6,922
Pods per lb. of Cured Cacao. ..	**12.5**	**12.8**	**12.2**	**12.9**	**14.9**	**12.1**	**14.3**	**13.0**
Pounds of Cured Cacao per acre. ..	**599**	**610**	**564**	**503**	**437**	**525**	**480**	**532**

TABLE 18.

KUMASI EXPERIMENT STATION:—ASHANTI.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Ocumare
Area of Field	4 acres
Planting Distance	12'x12'
Date of Planting.	1910–1916

	Number of Pods per acre.						
	1920	1921	1922	1923	1924	1925	Mean.
January	196	357	1,148	2,280	473	1,573	**1,004**
February	—	—	334	—	—	534	**145**
March	—	—	—	—	—	—	**0**
April	—	—	—	—	—	—	**0**
May	—	219	—	—	—	—	**36**
June	—	—	—	254	—	—	**42**
July	—	115	127	73	252	—	**94**
August	—	72	—	—	342	37	**75**
September	977	403	—	1,064	1,291	656	**732**
October	1,049	446	2,654	1,119	1,455	1,295	**1,336**
November	1,673	1,796	1,882	3,262	1,203	1,648	**1,911**
December	783	1,942	—	948	1,026	711	**902**
Totals	**4,678**	**5,350**	**6,145**	**9,000**	**6,042**	**6,454**	**6,277**
Pods per lb. of cured Cacao.	**12.1**	**11.5**	**11.9**	**14.5**	**11.7**	**12.1**	**12.5**
Pounds of cured Cacao per acre.	**386**	**466**	**516**	**621**	**499**	**583**	**502**

TABLE 19.

KUMASI EXPERIMENT STATION:—ASHANTI.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Cundeamor
Area of Field	4 acres
Planting Distance	15′x15′
Date of Planting	1908–1911

	Number of pods per acre.						
	1920	1921	1922	1923	1924	1925	Mean.
January	632	539	2,034	—	584	1,049	**806**
February	408	—	438	—	—	770	**269**
March	—	—	—	—	—	—	**0**
April	—	—	—	—	—	—	**0**
May	—	143	—	406	—	—	**91**
June	37	—	213	230	—	—	80
July	—	50	100	—	—	—	**25**
August	—	40	—	—	476	39	**92**
September	799	284	—	885	1,276	610	**642**
October	747	668	1,915	1,684	—	1,408	**1,070**
November	2,101	1,283	3,392	5,519	2,547	1,930	**2,795**
December	1,012	1,756	2,772	453	1,374	628	**1,332**
Totals	**5,736**	**4,763**	**10,864**	**9,177**	**6,257**	**6,434**	**7,202**
Pods per lb. of cured cacao.	**11.5**	**11.2**	**16.8**	**17.7**	**13.9**	**11.9**	**14.1**
Pounds of cured cacao per acre.	**498**	**425**	**646**	**518**	**450**	**500**	**511**

TABLE 20.

KUMASI EXPERIMENT STATION.—ASHANTI.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Criollo.
Area of Field	5 acres.
Planting Distance	12′ x 12′
Date of Planting	1910–1916.

	Number of pods per acre.						
	1920.	1921.	1922.	1923.	1924.	1925.	Mean
January	72	472	1,449	791	278	946	**668**
February	230	—	488	399	—	219	**223**
March	—	—	—	—	—	—	**0**
April	—	—	—	—	—	—	**0**
May	—	135	—	204	—	—	**56**
June	—	—	239	—	—	—	**40**
July	—	—	20	—	—	—	**3**
August	—	19	—	—	—	40	**10**
September	342	339	—	284	361	665	**332**
October	478	868	942	628	1,195	450	**760**
November ..	913	2,102	644	764	451	729	**934**
December	2,273	2,400	—	920	679	286	**1,093**
Total	4,308	6,335	3,782	3,990	2,964	3,335	4,119
Pods per lb. of Cured Cacao. ..	12.4	12.3	16.4	14.4	12.5	13.8	13.4
Pounds of Cured Cacao per acre. ..	348	515	231	277	237	241	307

TABLE 21.

PEKI-BLENGO EXPERIMENT STATION.—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado (Plot II).
Area of Field	2.3 acres.
Planting Distance	8′ x 15′
Date of Planting	

	Number of Pods per acre.													
	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean. 1915–25
January ...	—	3[illegible]7	[illegible]	230	1,461	1,858	622	291	472	569	543	361	1,418	**735**
February ...	—	20[illegible]	—	307	447	346	—	—	—	—	—	—	—	**100**
March ...	—	67	147	479	—	—	—	—	—	261	—	—	—	**81**
April ...	—	104	1,233	1,137	393	—	641	—	—	—	378	—	—	**344**
May ...	—	—	7[illegible]3	240	593	151	646	226	—	1,137	1,4[illegible]0	699	—	**533**
June ...	—	—	59	7	—	—	89	—	—	461	481	—	—	**100**
July ...	—	—	4	—	588	—	—	—	—	139	300	125	—	**103**
August ...	—	—	13	—	609	451	—	—	—	—	317	—	—	**132**
September ...	—	300	270	—	—	967	543	—	—	459	560	438	714	**359**
October ...	210	1,318	777	269	663	1,787	2,497	286	783	2,021	601	—	912	**963**
November ...	959	994	906	188	893	1,830	800	2,451	1,634	584	1,849	9,285	747	**1,924**
December ...	1,833	601	1,022	3,021	975	2,71[illegible]	1,077	3,101	[illegible]	1,205	923	—	—	**1,423**
Total ...	**3,002**	**3,974**	**6,013**	**5,878**	**6,682**	**10106**	**6,915**	**6,355**	**3,812**	**6,926**	**7,402**	**10,908**	**3,791**	**6,797**
			5,288			**7,901**			**5,698**			**7,367**		
Pods per lb. of Cured Cacao.							Not recorded.							
Pounds of Cured Cacao per acre.	***250**	**331**	**501**	**490**	**557**	**842**	**576**	**530**	**318**	**577**	**617**	**909**	**316**	

*Figures Estimated on the basis of 12 pods per pound of Cured Cacao.

TABLE 22.

PEKI BLENGO EXPERIMENT STATION:—EASTERN PROVINCE'
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado (Plot III,)
Area of Field	2.4 acres
Planting Distance	8'x15'
Date of Planting	1910.

	Number of pods per acre.													
	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean
January ..	—	380	180	140	868	3,098	1,107	266	592	773	496	567	1,359	753
February ..	—	150	—	215	347	489	—	—	—	—	—	—	—	92
March ..	—	5	45	417	—	—	—	—	—	197	—	—	—	51
April	—	—	529	608	319	—	1,131	—	—	—	329	154	—	236
May	—	—	415	150	374	292	644	277	—	538	772	20	—	268
June	—	—	25	—	—	—	62	—	—	271	220	—	—	44
July	—	—	155	—	266	—	—	—	—	77	167	—	—	51
August ...	—	—	—	—	398	411	—	—	—	—	114	—	—	71
September ..	—	131	—	—	—	422	310	—	—	77	159	84	686	136
October ...	83	415	290	132	200	1,264	2,072	76	431	459	258	—	875	504
November ..	622	365	688	1,834	1,040	2,218	3,041	2,446	843	528	650	615	716	1,200
December ..	1,319	449	1,180	1,838	1,967	1,107	1,357	2,299	809	993	—	—	—	1,024
Totals ..	2,024	1,895	3,507	5,334	3,779	9,301	9,724	5,364	2,675	3,913	3,165	1,440	3,636	4,430
	—		3,602			7,601			3,984			2,747		—
Pods per lb. of cured cacao.						not recorded								
Pounds of cured cacao per acre.	**169	158	292	445	315	775	810	447	225	326	264	120	303	—

**Figures Estimated on the basis of 12 pods per pound of cured cacao.

TABLE 23.

PEKI BLENGO EXPERIMENT STATION:—EASTERN PROVINCE.
YIELDS OF CACAO PER ACRE.

Variety of Cacao	Ocumare.
Area of Field	2 acres
Planting Distance	12'x10'
Date of Planting	1913.

	Number of pods per acre.									
	1917	1918	1919	1920	1921	1922	1923	1924	1925	Mean.
January	66	1,310	339	945	517	452	415	559	629	**581**
February	10	135	—	—	—	—	—	—	—	**16**
March	—	—	—	—	—	155	—	—	—	**17**
April	—	—	241	—	—	—	153	—	—	**44**
May	20	26	132	—	—	463	698	307	—	**183**
June	—	—	20	—	—	195	329	—	—	**60**
July	36	—	—	—	—	105	185	34	—	**40**
August	17	62	—	—	—	—	102	—	—	**20**
September	—	41	—	—	—	231	244	302	251	**119**
October	5	639	—	—	584	492	425	666	647	**384**
November	—	1,046	632	930	938	422	891	—	874	**637**
December	372	425	1,458	1,310	417	1,446	770	1,147	—	**816**
Totals	526	3,684	2,822	3,185	2,456	3,961	4,212	3,015	2,401	2,917
		2,344			**3,201**			**3,209**		
Pods per lb. of cured cacao ..	**11.1**	**11.2**	**8.4**	**10.6**	**10.7**	**11.6**	**11.0**	**11.1**	**11.4**	—
Pounds of cured cacao per acre ..	**47**	**329**	**336**	**300**	**229**	**341**	**379**	**271**	**210**	—

TABLE 24.

PEKI-BLENGO EXPERIMENT STATION.—EASTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Cundeamor.
Area of Field	2 acres.
Planting Distance	12′ x 10′
Date of Planting	1913.

	Number of Pods per acre.									
	1917.	1918.	1919.	1920.	1921.	1922.	1923.	1924.	1925.	Mean.
January	22	1,214	465	811	560	161	439	314	866	539
February	—	318	—	—	—	—	—	—	—	35
March	—	—	—	—	—	11	—	—	—	1
April	—	—	90	—	—	—	45	—	—	15
May	37	34	18	—	—	165	244	79	—	82
June	—	—	3	—	—	64	119	—	—	21
July	—	—	—	—	—	5	28	25	—	6
August	—	—	—	—	—	—	10	—	—	1
September ..	—	2	—	—	—	20	30	54	58	18
October	—	320	—	—	212	151	90	204	262	138
November ..	—	403	271	809	369	447	628	—	416	371
December ..	160	286	1,417	1,338	111	1,073	534	537	—	606
Total ..	219	2,577	2,264	2,958	1,252	2,097	2,167	1,213	1,602	1,833
		1,687			2,102			1,660		
Pods per lb. of Cured Cacao ..	16.9	12.2	9.9	12.3	12.3	14.1	12.1	21.0	11.2	
Pounds of Cured Cacao per acre ..	13	211	218	240	101	141	179	57	143	

TABLE 25.

WIAWSO EXPERIMENT STATION.—WESTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Amelonado.
Area of Field	3 acres.
Planting Distance	12′ x 12′
Date of Planting	May, 1916.

	Number of Pods per acre.					
	1921.	1922.	1923.	1924.	1925.	Mean.
January	392	—	1,282	984	1,785	**889**
February	229	617	21	92	176	**227**
March	—	77	26	40	57	**40**
April	—	—	277	275	102	**131**
May	—	—	554	63	257	**175**
June	278	56	461	—	37	**166**
July	—	17	175	1	—	**39**
August	—	—	165	—	—	**33**
September	395	31	331	13	182	**190**
October	1,069	389	404	197	860	**583**
November	850	958	2,647	273	2,037	**1,353**
December	1,929	1,005	801	492	—	**845**
Total	**5,142**	**3,150**	**7,044**	**2,430**	**5,493**	**4,652**
Pods per lb. of Cured Cacao.	**13.2**	**14.5**	**11.2**	**15.2**	**17.3**	**13.6**
Pounds of Cured Cacao per acre.	**389**	**217**	**629**	**160**	**312**	**343**

TABLE 26.

WIAWSO EXPERIMENT STATION. -WESTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Ocumare.
Area of Field	2½ acres.
Planting Distance	12′ x 12′
Date of Planting	May. 1926.

	Number of Pods per acre.					
	1921.	1922.	1923.	1924.	1925.	Mean.
January	1,020	—	1,814	533	2,142	1,102
February	390	924	96	431	212	411
March	—	122	109	65	69	73
April	—	—	566	330	149	207
May	—	—	876	76	381	267
June	538	76	585	—	60	252
July	—	64	116	1	—	36
August	—	—	69	—	1	14
September	406	30	197	16	153	160
October	388	180	1,412	237	798	603
November	903	1,079	1,581	328	1,791	1,136
December	3,288	1,469	2,236	591	3	1,517
Total	6,933	3,944	9,674	2,608	5,759	5,778
Pods per lb of Cured Cacao. ..	11.2	12.5	12.6	14.3	12.8	12.4
Pounds of Cured Cacao per acre. ..	619	315	766	182	450	466

TABLE 27.

WIAWSO EXPERIMENT STATION.—WESTERN PROVINCE.

YIELDS OF CACAO PER ACRE.

Variety of Cacao	Cundeamor.
Area of Field	2½ acres.
Planting Distance	12′ x 12′
Date of Planting	May, 1926.

	Number of Pods per acre.					
	1921.	1922.	1923.	1924.	1925.	Mean.
January	988	—	2,496	1,510	2,632	**1,525**
February	459	1,294	163	337	276	**506**
March	—	186	40	46	56	**66**
April	—	—	193	399	186	**156**
May	—	—	512	96	362	**194**
June	500	106	569	—	52	**245**
July	—	57	170	12	—	**48**
August	—	—	140	—	—	**28**
September	419	39	254	28	132	**174**
October	389	133	1,185	228	601	**507**
November	593	1,027	1,570	232	1,660	**1,016**
December	2,781	790	1,558	748	448	**1,265**
Total	**6,129**	**3,632**	**8,850**	**3,636**	**6,405**	**5,730**
Pods per lb. of Cured Cacao. ..	**11.9**	**12.0**	**12.2**	**14.6**	**14.8**	**12.9**
Pounds of Cured Cacao per acre. ..	**515**	**303**	**725**	**249**	**433**	**381**

BULLETIN No. 5.

Department of Agriculture,

Gold Coast.

"COLLAR CRACK" OF CACAO.

(ARMILLARIA MELLEA (VAHL.) FR.)

BY

H. A. DADE, A.R.C.S.,

Mycologist.

Accra, January, 1927.

GOLD COAST.

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1927.

FOREWORD.

This is a clear and careful account of a disease discovered in Togoland for the first time in this country a few years ago. It has, fortunately, not a wide range except in Togoland where energetic measures are being taken to deal with the disease. But as it has many wild hosts a continual watch must be kept not only for areas newly attacked but for repetition in areas previously treated.

C. H. KNOWLES,
Director of Agriculture.

Accra,
24th December, 1926.

CONTENTS.

"COLLAR CRACK" OF CACAO.

(Armillaria mellea (Vahl.) Fr.)

"Collar Crack" is widely distributed in the cacao-growing area of the Gold Coast Colony, and of the adjacent Mandated Territory of Togoland.

Extensive damage and severe loss is occasioned by this disease in some districts, especially in Togoland, from which it was first reported.

In the following pages numbers in brackets, thus—(3)—are references to the bibliography, page 21.

Plates I to V (upper), photographs by R. H. Bunting.

Plates V (lower) to XVII, photographs by H. A. Dade.

Figures in text by H. A. Dade.

PATHOLOGY.

Name.

The common name "Collar Crack" was applied to this disease as being descriptive of its most evident and characteristic symptom.

History.

Collar Crack was first reported in the Kpoeta district of Togoland in 1922 by Mr. G. H. Eady, Superintendent of Agriculture. This area was visited by the author shortly afterwards, and investigation instituted. Attack was found to be severe, and to endanger a large section of the cacao area. The causative organism was not at first recognised, owing to the sporophores found being in a state of decay, and it was thought that a species of Tricholoma was responsible. Specimens afterwards found established its identity as a species of Armillaria.

After the badly attacked farms had been under observation for a year it was deemed advisable to institute legislation for control, and to this end a Proclamation by H.E. the Governor was made in November, 1923. (1). The prescribed operations were begun shortly afterwards, and Mr. H. Nicholas has since been in charge of these. In January, 1924, the Plants (Injurious Pests) Ordinance (2) came into action, and the work has continued under this instrument since the Mandated Territory of Togoland came under the same administration as the Gold Coast in April, 1924.

Since the disease was first recorded it has been found to be very widely distributed throughout the Gold Coast. It is now being systematically controlled by Inspectors of Plants under the Ordinance.

Range.

The disease is known in all parts of the cacao-growing area of the Gold Coast. New localities are constantly being reported, and it is evident that the causative fungus is present throughout the forest belt.

Importance.

It is not at present possible to assess the loss caused by Collar Crack in significant figures. In Togoland large areas are involved and in these areas the attack is intense. Large sections of farms, and frequently complete farms, are destroyed in a short time. (Plate XVII.) In the Gold Coast itself such extreme cases have not been found. Although much damage is sometimes done, generally only small groups of trees standing in situations favourable for attack are destroyed. Even in such cases the loss is frequently of distinct economic importance.

In individual cases the progress of attack is so rapid that there is little chance of its being observed before it has proceeded too far for therapeutic treatment. The whole of the transportation and mechanical tissues is quickly involved.

SYMPTOMATOLOGY.

Parasitised trees exhibit very characteristic symptoms. Having regard to the rapidity with which attack progresses wilting does not occur so soon as might be expected. In some cases wilting and subsequent loss of foliage occurs before the fall of the tree, as in Plate I, but it is found that in the majority of cases wilting does not take place until the damage to the trunk is very far advanced, and that frequently the collapse of the tree occurs before wilting begins.

In all cases the diagnostic symptom is the occurrence of a number of conspicuous longitudinal fissures, which appear at the collar and quickly extend up the trunk. (Plates I., II., III.,) They are longer and more numerous on one side of the tree—the side on which infection took place. (Fig. 3 and Plate XIII.) Frills of extruded xylostroma, which protrude from the cracks, render the latter even more conspicuous. These are at first cream-coloured, becoming dark brown with age. (Plate VIII, left.)

Sometimes the cracks extend to considerable heights—eight or ten feet—but usually the tree is dead by the time they have attained to a height of three to five feet above the ground.

A transverse section of the attacked trunk shows that the cracks are radial, occurring more thickly on the side of the trunk on which the fungus entered. (Plate XIII.) Numerous cracks are formed, only the larger ones being apparent from the outside, where the bark is also split.

The fissures are closely packed with sheets of somewhat leathery xylostroma—white or cream-coloured—(Plate XIV,) which sooner or later protrude from the split bark as the lobed and somewhat crimped frills.

The cracks follow the line of the medullary rays. In addition to this radial system a few other irregular fissures usually occur. (Plates XIII and XIV.)

When the felled trunk is cut up into lengths the damaged sections fall apart into segments. The plates of xylostroma can then be seen clearly, with their fan-shaped advancing margins. (Plate IV.)

From the point of infection—a lateral root—the cracks are found to extend downwards into the tap-root as well as upwards into the trunk.

The damage caused by the fungus is frequently followed by a wet rot which reduces the tap-root to an evil-smelling bright yellow pulp. Collapse of the tree follows the weakening of the mechanical support caused by the cracks and the destruction of the tissues.

In some cases the production of fructifications of the fungus ensues rapidly. Farms have been seen in which every tree, still standing, has had its base enveloped in large clusters of "mushrooms". These are illustrated in Plates I., III., V., VI., and VII., and are described in a later page.

ETIOLOGY.

The Pathogen.

The organism causing Collar Crack is *Armillaria mellea* (Vahl.) Fr., variety not named.

The first sporophores seen, which were found in great numbers by the author at Kpoeta, were all in a state of incipient decay. This rendered exact determination impossible, but a species of Tricholoma was suspected. Subsequently Mr. R. H. Bunting, Mycologist, found more perfect specimens, and after this large numbers of good specimens were obtained from different sources, and induced to form in the laboratory. They were then seen to be sporophores of an Armillaria, but not quite typical of a known species. Specimens were therefore submitted to Miss E. M. Wakefield, of the Kew Herbarium, who at that time had also under examination similar specimens from Uganda, where this fungus

causes a root-rot of coffee, and is also found on cacao and numerous other hosts. (3). Miss Wakefield kindly furnished a report, which is quoted below :—

> "*Armillaria.*—This is apparently exactly the same as specimens received from Uganda found in connection with diseased roots of coffee, rubber and other plants. Both are very close to *Armillaria mellea,* and the Uganda species has been published as such. As regards the fructification, there are no differences that might not occur between individuals. The microscopic characters of spores and pileus scales are similar, but the African forms seem in general to be more dwarfed, and more deeply coloured than those of temperate regions. No mention is made of rhizomorphs in connection with the Gold Coast specimens. If these occur, then it would seem quite in keeping with the facts to regard the species at *Armillaria mellea,* modified somewhat by the conditions obtaining in the tropics."

(Rhizomorphs were afterwards demonstrated—see page 11.)

A number of diverse forms of *A. mellea* are known. In Great Britain alone ten widely different varieties in addition to the type are recognised. (4) There is a wide range of individual variation in the Gold Coast form. Having regard to its identity with the Uganda fungus, it appears probable that this form is widely distributed in tropical Africa.

Suscepts.

A. mellea is known in many parts of the world as a common saprophyte, and as a parasite of many forest and orchard trees. Without attempting to give a complete list, the following hosts are known—beech, birch, apple, cherry, plum, peach, magnolia, tulip, chestnut, citrus, coffee, oak, pear, pines, walnut, acacia, cinchona, figs, olive, mango, poplar, Hevea, tea. It is also found on smaller plants such as raspberry, potato, bramble, gooseberry, docks. It is economically important in Europe, America and Australia, causing much damage to timber trees and orchard crops. In Uganda it is known on coffee, tea, Para and Ceara rubber, cacao, mango, guava, Ficus, Eucalyptus, Spathodea, Bauhinia, Erythrina, Hibiscus, roses. (3). In North Africa it causes considerable loss to fig growers.

Gold Coast hosts at present known are :—

Wild :—Pittosporium sp. (prob. nov. spec.), Rauwolfia vomitoria, Phyllanthus discoideus, Ficus asperifolia ("sandpaper tree"), Chlorophora excelsa (odum), Cola acuminata (kola), Spathodea campanulata (tulip tree), Blighia sapida, Funtumia africana, Terminalia spp., Combretum spp., Pennisetum purpureum (elephant grass), Elaeis guineensis (oil-palm), Alchornea cordata. *Cultivated* :—Avocado pear, lime, mango, coconut, coffee, plantain, cocoyam (Colocasia antiquorum.), cassava, okro (Hibiscus esculentus), pepper (Capsicum.)

The wild hosts have been kindly determined by Mr. F. N. Howes, Government Botanist.

It is therefore evident that *A. mellea* has a very wide range of hosts, and this, together with its saprophytic habit, favours its distribution and increases the difficulty of control.

Description of the Sporophore.

Plates V, VI and VII) *Armillaria mellea (Vahl) Fr.* Gold Coast form. *Pileus* 1.5—7 cm., normally 4—5 cm., pale cream to honey coloured, with regularly scattered brown squamules (the remains of the volva), fleshy, convex at first, then flattened, finally more or less concave, paler at the margin, striate. In young sporophores intact volva tawny brown.

Stipe.—2 x 0.3—7 x 0.6 cm., normally 5 x 0.5 cm., cream to dark brown, scaly below the annulus, elastic, fibrillose, apex striate, darkening with age, equal at base.

Annulus white, membranaceous, fugaceous.

Gills similar in colour to, but somewhat paler than, the pileus, subundulate, adnate, decurrent by a tooth, subdistant.

Spores hyaline, elliptical-ovate, 7 x 6—8 x 7 microns.

The sporophores arise in clusters from the collar of the tree, close to ground level. (Fig. 3 and Plates I., III. and V.)

Xylostroma and Rhizomorphs.

The structure of the xylostroma extrusions, which appear on the trunk as frills projecting from the cracks, is of interest. The structure of the highly organised rhizomorphs of *A. mellea* was described by de Bary (5). The structure of the xylostroma sheets, as they occur under bark, was described by Hartig (6) as similar to that of the rhizomorphs, except for modifications due to their different form, and for the absence of colour. The frilly extrusions found in Collar Crack show an intermediate structure, due presumably to the conditions under which they exist. They are, like rhizomorphs, free from contact with the walls of the cracks between which the xylostroma sheets are compressed. Plate XI shows the typical large-celled internal tissue, the thickened cortical cells, and the external gelatinous layer, all of which correspond with typical rhizomorph structure. When freshly extruded the frills are cream-coloured, but darken with age through dark brown to black. They are fleshy at first, but become brittle, like the rhizomorphs, later.

A hyper-parasite, apparently a species of Hypomyces, has been found growing on these structures by Mr. Bunting.

No function can be ascribed to the frills, which do not develop further.

Rhizomorphs have not been found in the field, but attempts to produce them in the laboratory have never failed. Large pieces of infected collar and tap-root are placed in four-gallon kerosene cans, loosely packed with wet moss, and kept damp. This treatment invariably induces the formation of sporophores and rhizomorphs. Plates VIII and IX show rhizomorphs which have been thus obtained. They exhibit the typical structure of the rhizomorphs of *A. mellea,* and also regular dichotomy. The latter is conspicuous owing to there being under cultural conditions no mechanical obstruction to growth such as occurs in soil. Their colour is deep brown to black, the growing points white owing to the incomplete development, in this region, of the cortical layer which carries the colour. In early stages the tips are covered with a tuft of loose gelatinous hyphae. Their histologic structure conforms with the type description (5). They are produced from the the general xylostromatic mass, usually within the host axis, and emerge after pursuing a more or less contorted path within the fissure, in which they are flattened and distorted.

Rhizomorphs are also formed in tube cultures. (Plate X.)

Pathogenicity.

A. mellea is stated by some authors to be commonly a wound or a secondary parasite. Others, recently Gard (7), are convinced of its ability to attack perfectly healthy trees. In the Gold Coast this fungus is undoubtedly a very virulent parasite—it can attack trees which show no signs whatever of other damage. Trees of all ages are attacked.

Infection begins in lateral roots—in most cases in this country the lateral feeding roots of cacao are found very close to the surface, this being the natural response to the structure of the prevailing types of heavy soil. The infection is then communicated to the main axis, and spreads both into the tap-root and into the trunk. The bark at the point of entry is rapidly permeated by mycelium, which spreads up and round the trunk. If a cut be made into the bark, white streaks and aggregations of xylostroma can be seen in its thickness. (Plate XIV.) In the typical mode of attack of *A. mellea,* as found elsewhere, sheets of xylostroma are formed between the bark and the wood ; but in the case of the Gold Coast form, parasitising cacao, these sheets are not formed at all, or are only very imperfectly developed, in this position. In only one case have well developed xylostroma sheets been found between bark and wood.

From the bark the mycelium penetrates into the medullary rays, and hyphæ enter the cells and quickly grow along the rays. The mechanism of the formation of fissures can be seen at work in all stages by a careful examination of cases in the earlier stages of attack, such as are shown in Fig. 3, I., and II.

Having exhausted the ray cells the mycelium becomes elaborated into xylostroma. A number of these small parallel strips of xylostroma come into being in adjacent rays. The wood of cacao and of other Sterculiaceous trees, is abundantly supplied with large medullary rays. (Fig 1.) In an average tangential section through

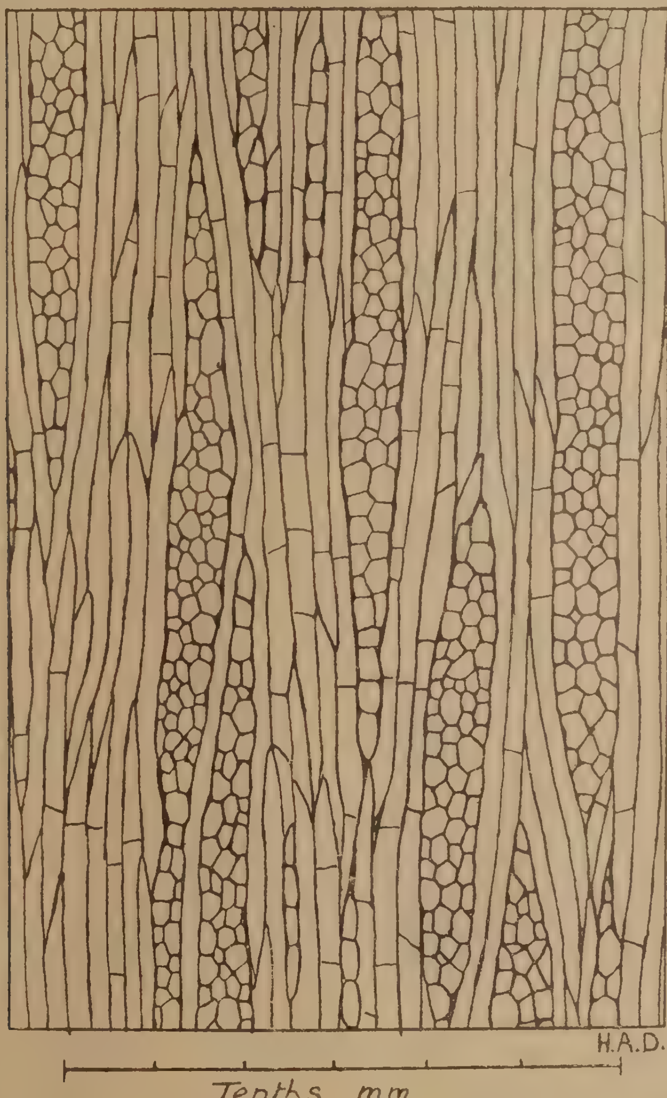

Fig. 1. Camera lucida drawing from a tangential section of trunk sap-wood, showing the large area occupied by the medullary rays.

the trunk sap-wood the medullary rays occupy thirty per cent of the total area. The accumulated lateral disruptive effect exerted simultaneously by many strips of rapidly growing xylostroma is

considerable. The wood of cacao is soft and weak, and very susceptible to cracking in healthy trees under the stresses set up by badly balanced growth or slight mechanical shocks. The formation of strips of xylostroma in vertically adjacent rays therefore results in a slight crack in the plane of the rays. Fig 2 is a drawing,

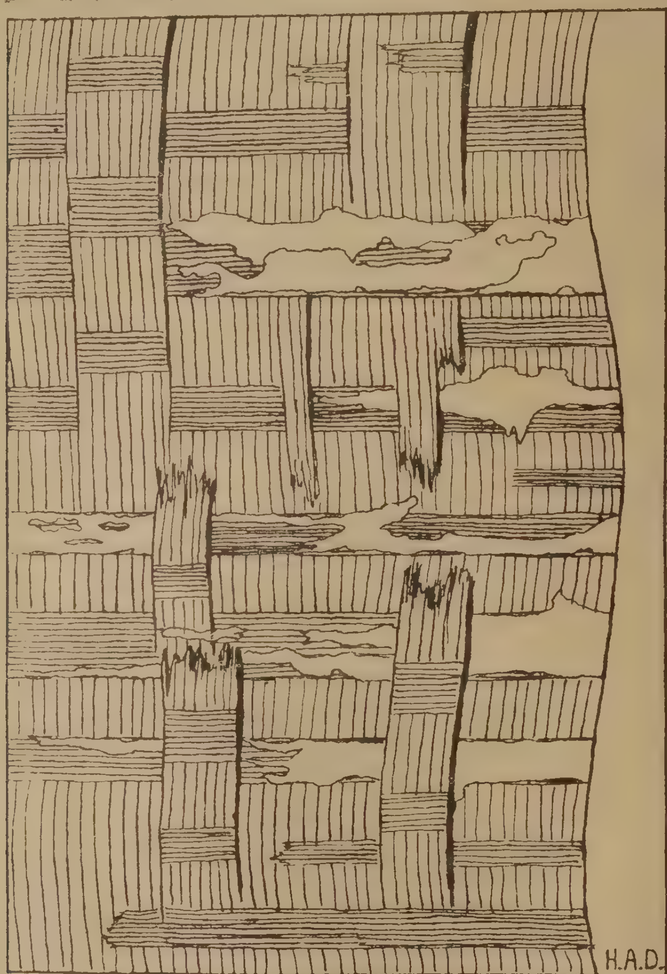

Fig. 2. The formation ot xylostroma in medullary rays. Wood fibres indicated by vertical lines, medullary rays by horizontal lines, xylostroma white.

somewhat diagrammatic, of an actual case in this stage. Such examples may be found by carefully stripping off thin layers of wood from the face of a segment of a diseased tree, in the region where infection of the wood is taking place from bark into which the mycelium has recently spread. In Fig 2 the crack has just started and the xylostroma is beginning in some places to extend vertically into the openings thus formed. Progressive thickening and growth

of the plate of xylostroma causes the further extension of the crack. The fan-shaped growing edges of a large and vigorous plate are seen in Plate IV.

When once they have been started, the extension of the cracks is no doubt assisted by the stresses set up in the wood by the weight of the tree. This agency is also most probably the cause of the few fissures, frequently seen, which do not follow the course of the medullary rays. (Plate XIV.)

Drying out of the wood, caused by interference with the water current by the destruction of the lower tissues, also probably has some effect on the subsequent opening out of the cracks.

As already indicated, a section across a diseased collar shows that most damage has occurred on the side on which the fungus entered the main axis, the opposite side showing fewer cracks and more or less healthy wood. (Plate XIII.) As the invasion progresses the bark on the latter side becomes involved and cracks are started. The tree is killed, or collapses, before all the healthy wood is destroyed. Fig. 3 shows diagrammatically the progress of the attack. It will be seen that owing to the rapid extension of

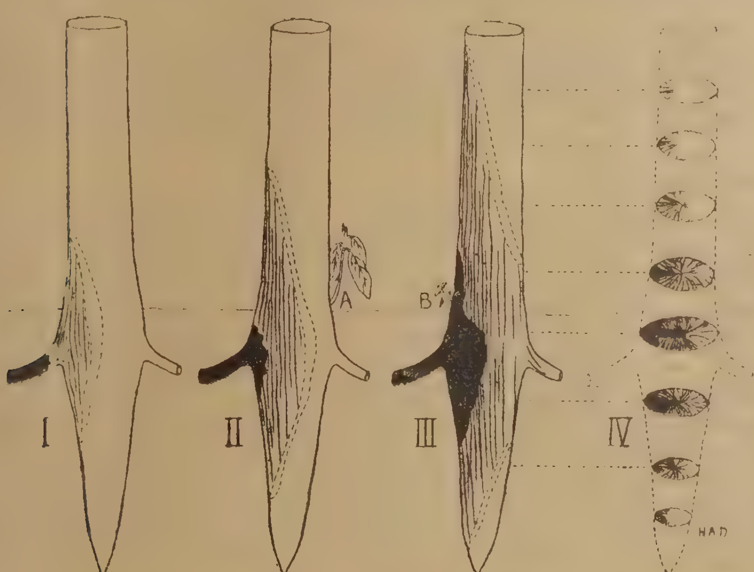

Fig. 3. Diagram showing the progress of attack. Infection through a lateral root on the left. Rotted wood shown in black. Circumferential spread through the bark is slower than vertical spread through the cracks. In IV a series of sections through III shows the radial extension of cracking. A—site of production of suckers, B—site of production of sporophores.

the cracks infection spreads more quickly vertically than circumferentially.

The existence of a certain amount of healthy bark and wood on the side remote from original infection sometimes makes possible the formation of suckers, which may attain to some size. (Fig. 3.) This has led to a few reports of cases of recovery. There is as yet no evidence to show that these suckers can resist infection from the adjacent diseased collar, and it is extremely improbable that they can escape eventual destruction unless very careful and difficult surgery and protective treatment is practised. The question is hardly of economic importance, in view of the extreme rarity of even an abortive attempt at recovery.

The xylostroma having progressed into the cracks, hyphæ grow out laterally from it and penetrate into the adjacent cells, the contents of which are exhausted. Hasenöhrl and Zellner (8) were unable to find cellulose—and lignin—splitting enzymes in *A. mellea*, In Collar Crack the lignified cell-walls survive. In wood which suffers no secondary attack, but which has been completely exhausted by *A. mellea*, this is seen when an attempt is made to saw through a trunk and then to trim the cut surface. Owing to the breaking down of connective tissue the lignified elements remain as a loosely packed mass which resists all efforts to produce a smooth surface. This can be seen in Plates XIII and XIV.

The wet rot previously referred to as following *A. mellea* attack is possibly bacterial. A species of Bacillus always present in the slime has been isolated, but has been found incapable of functioning as a primary parasite on root wounds made under aseptic conditions.

Transmission.

The infection of new individuals by *A. mellea* is usually attributed to the agency of rhizomorphs. As stated above, rhizomorphs have not been found in natural conditions in the Gold Coast, although many hundreds of cases have been examined by the author. In a very few cases what appeared to be an abortive attempt at rhizomorph formation has been observed, a very short outgrowth of distorted xylostroma similar to the frilly extrusions, adapting itself to soil crevices, and attaining a length of perhaps two centimetres. In each case the growth was dead and decaying. No strong evidence has been obtained to account for the absence of rhizomorph formation in the field, but it is assumed that the character of the soil inhibits it. In areas where *A. mellea* is found the prevailing type of soil is an extremely stiff clay.

In each of the hundreds of cases which have been carefully examined infection has been found to be due to actual contact of the host's roots with other diseased roots or rotting wood. The complete clearing of farms at their inception is not an economic possibility, and a certain amount of timber and forest tree roots are inevitably present. This material causes the introduction of

many root diseases from the surrounding bush. This subject is fully dealt with by Nowell (9). Once *A. mellea* has obtained a footing in a cacao farm, rapid spread is possible owing to the fact that the root systems of all adjacent trees are in contact, even in farms where trees are properly spaced. Transmission by root contact is illustrated by Plates XV and XVI. Plate XV shows an Eriodendron root which had been severed from the parent tree and upon which *A. mellea* was growing saprophytically. Thirty-three yards of this root were uncovered, and in its course it was found to have infected six cacao trees, three of which appear—labelled—in the photograph, by contact with their lateral roots. Plate XVI shows a lateral root of one of these trees in contact with the silk-cotton root. At the time of examination infection had advanced nearly to the main axis of the new host.

Correlated Condition.

The only environmental condition which appears to be associated with intensity of attack is that of humidity. The district from which Collar Crack was first reported is situated in a large massif in altitudes up to 2,700 feet. Intensity of attack was found to be less on the lower slopes of the block. That altitude is in itself not a determining factor was shown by the subsequent discovery of the disease in much lower situations (400 feet.)

The higher hills and ridges in the Gold Coast are enveloped in clouds during the night, and, in the rainy season, during a considerable part of the day. They are clothed in forest, which conserves the atmospheric moisture during the day. Condensation from the mists is very heavy.

The factor which is of greatest significance in connection with the severity of attack of all cacao diseases caused by fungi in the Gold Coast is atmospheric and soil humidity. The degree of humidity is not of course entirely due to rainfall, but is the result of soil structure and of the type of vegetation and shelter. Recorded Relative Humidity in typical cacao districts in the Gold Coast varies between eighty and ninety-five degrees, even in the dry season. But these data are taken in meteorological stations in open and ventilated situations, and the average Relative Humidity in cacao farms has been found to be very much higher. In farms humidity is increased and maintained by the consistent neglect of the native peasant farmers, in whose hands the cacao industry is, and who do not practise cultivation. The farms are consequently very thickly overgrown with weeds, trees are never pruned, and are frequently covered with epiphytes. Ventilation is therefore reduced to a minimum. Trees commonly have the lower part of the trunk invested with a thick, long growth of mosses and liverworts. Under these circumstances the constitutions of trees are adversely affected, and they are less resistant to disease. At the same time optimum conditions for the growth of fungi obtain.

Climatic and edaphic conditions in the Gold Coast are exceptionally favourable to cacao, which here will apparently survive a much greater degree of neglect and wrong treatment than in other cacao-growing countries. But in excessively humid conditions such as are described above the trees are always very susceptible to all cacao diseases, the loss from which can be greatly reduced by weeding and ventilation.

Excessive humidity is found to prevail elsewhere in the Colony where Collar Crack is found. In lower altitudes, *e.g.*, Asamankese (450 feet), it is very commonly found on the banks of streams, where the water table is maintained at a high level. In higher altitudes, *e.g.*, the Togo area and Kibi (1,200 feet), where greater atmospheric humidity prevails, its incidence is not confined to the neighbourhood of streams.

In other countries excessive soil humidity is found to be correlated with severity of attack by *A. mellea*, as in the cases of potato disease in Scotland, where heavy wet soil is suspected to be a contributory factor (10), of goosebery disease in England, where attack took place on badly drained ground (11), and of Morocco, where the fungus occurs everywhere in abundantly irrigated places (12).

Collar Crack can be controlled by (i) reducing the excessive humidity by cutlassing weeds, ventilating the farms and by drainage where necessary ; (ii) eliminating diseased trees and material upon which the fungus can grow as a saprophyte ; (iii) by isolating affected ground by means of trenches.

Sanitation as practised in the Gold Coast includes the complete removal and destruction by fire of the diseased tree and roots. Trenches two feet deep are dug around the affected area. Barss (13) suggests the construction of concrete walls in the trenches. This is not economically possible in the Gold Coast, and in view of the fact that rhizomorphs are not found in the field would appear to be superfluous. The important point in trenching is to remove from the trench all roots and wood which may serve as bridges for the fungus.

In properly planted plantations the square system of trenching is effective and capable of unlimited extension if necessary. In this method a square trench is dug round the diseased tree, and a second large square trench is dug round the adjacent eight trees. Should any of these adjacent trees have become infected from the first the second trench will prevent infection of more distant trees. Native farms in this country are not planted in rows, and consequently trenches are of irregular shape, and not so easily extended.

A. mellea has many wild hosts, and a close watch should be kept on bush trees surrounding the farms, and on shade trees in them. Its omnivorous parasitism and in addition its saprophytic habit increase the difficulty of eradicating this fungus from farms surrounded by bush.

Therapeutic treatment of infected trees is not usually possible, for attack proceeds so rapidly that a large part of the tree is involved before it is observed. The beginning of attack is sometimes revealed when digging out neighbouring dead trees. In these cases drastic root pruning in the vicinity of the contact should be practised, all severed roots and other dangerous material removed, the hole should be treated with lime if possible, and the surfaces of pruning wounds with an antiseptic and a protective paint. The hole should be left open in order to allow the free passage of air and to discourage fungus growth in the neighbourhood of the wounds. In the Gold Coast the use of three per cent carbolineum as an antiseptic and white lead paint as a protective coating is recommended. It may be of interest to refer to other methods as providing suitable alternatives. Humphrey (14) recommends painting the bark with shellac and afterwards treating the wound with a 25 :75 mixture of coal-tar creosote and asphaltum for delicate trees such as peach, cherry, plum, magnolia and tulip, or shellac alone for small wounds. Barss (13) recommends treatment with Bordeaux paste and exposure to air. (Bordeaux paste is made by dissolving one pound of Copper Sulphate in one gallon of water and separately slaking two pounds of lime in half a gallon of water. When cool, the two are mixed and stirred. Sugar, four ounces to the gallon, improves keeping qualities. Bordeaux paste is a temporary protection only.) Gard (15) recommends, after surgery, cauterisation with sulphate of iron and sulphuric acid, or with copper sulphate.

Legislation.

Armillaria mellea is scheduled as an "injurious pest" in the Plants (Injurious Pests) Ordinance of 1923 (2). This ordinance has as its object the protection of the cacao industry—the principal source of wealth of the country—and was necessitated by the neglect of the illiterate farming community. The Ordinance provides for initial sanitary treatment of farms by gangs controlled by Inspectors of Plants, and for subsequent periodical inspections. Failure on the part of the farmer to maintain his farm in a sanitary condition and to apply the "prescribed treatment" to all cases of attack by "injurious pests" is an offence punishable by fines or imprisonment.

Under the Ordinance the treatment prescribed for Collar Crack is the removal and immediate destruction by fire of all diseased material, and the isolation of the affected area by trenches two feet deep.

SUMMARY.

(1) Collar Crack is a destructive and rapidly spreading disease of cacao widely distributed throughout the forest belt of the Gold Coast and Togoland.

(2) Characteristic symptoms are exhibited, notably the conspicuous longitudinal radial cracks produced in the collar of the tree.

(3) The causative organism is a variety of *Armillaria mellea* (Vahl.) Fr., which is described.

(4) This fungus has a very wide range of cultivated and wild hosts, and also lives as a saprophyte on dead wood.

(5) The histology of highly organised tissue which protrudes from the cracks is of interest as linking the structure of xylostroma with that of rhizomorphs.

(6) Rhizomorphs are not found in natural conditions, but can be readily induced to form in laboratory culture.

(7) The causative fungus is a virulent parasite not depending on wounding or previous infections for entry into the host.

(8) Infection begins in lateral roots and extends into the main axis, where fissures are produced by interesting mechanical phenomena—*i.e.*, rupture of the wood tissue by plates of xylostroma originating in medullary rays.

(9) Thoroughly lignified cell-walls are not destroyed.

(10) Transmission is by actual root contact.

(11) The only significant environmental factor correlated with severity of attack is excessive humidity.

(12) Control is effected by reduction of humidity, destruction of morbid material, and isolation of the affected areas; occasionally by therapeutics.

(13) Legislation has been found necessary in the Gold Coast and Togoland to ensure effective control, and has been instituted.

H. A. DADE.

Mycologist.

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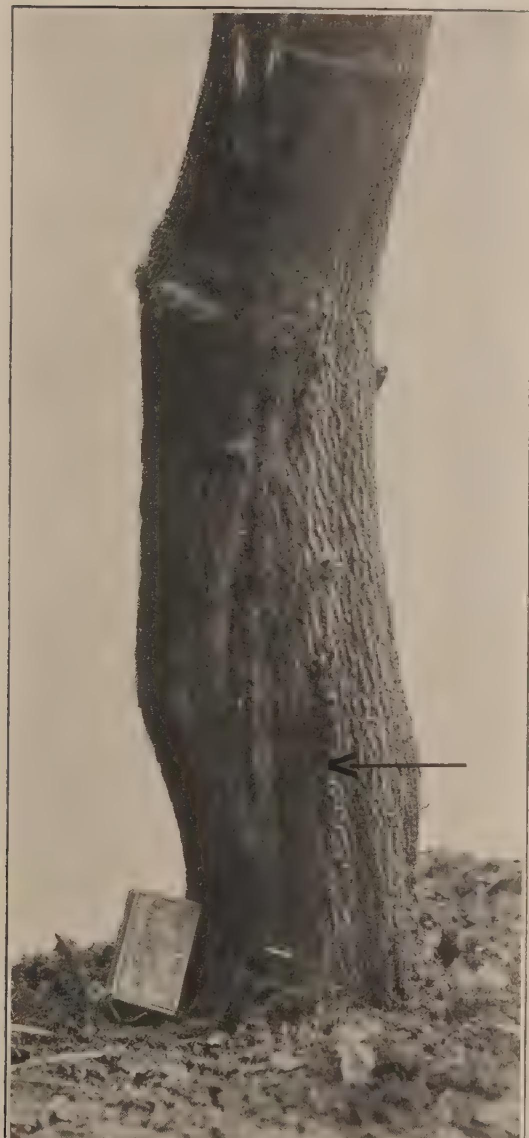
PLATE I.

Cacao Tree killed by Armillaria Mellea. (See pages 8, 9, 11).

PLATE II.

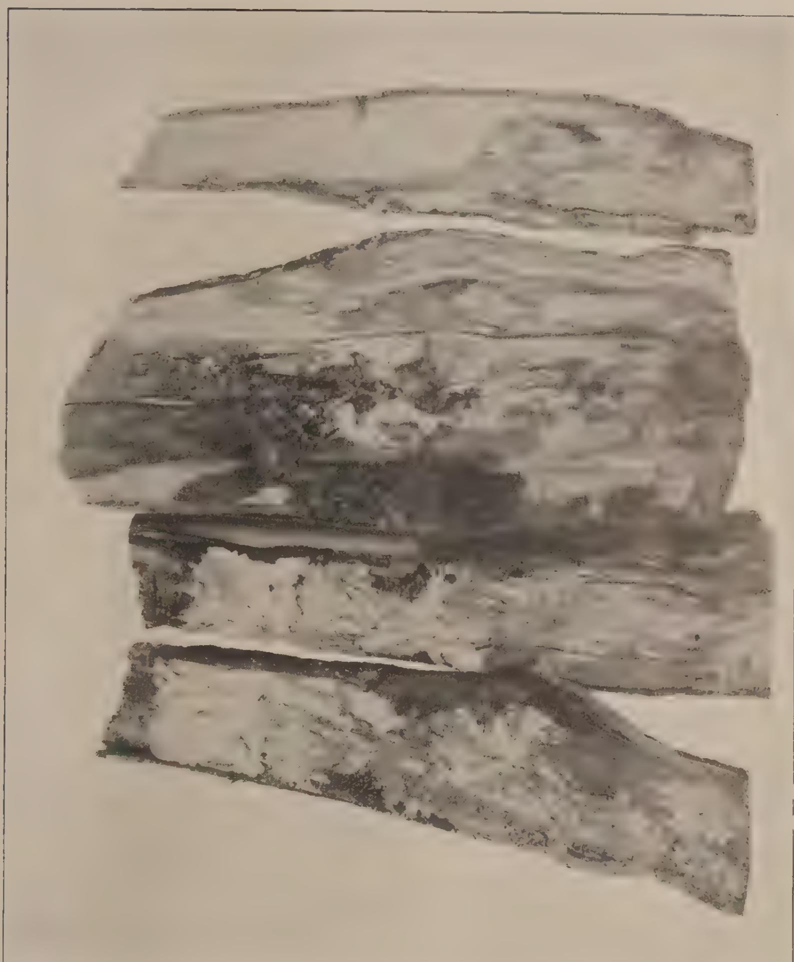


Trunk of Cacao Tree infected with Armillaria Mellea. (See page 8.).

PLATE III.

Sporophores of Armillaria Mellea on Collar of Cacao Tree. (See pages 8, 9.)

PLATE IV.



Collar of a Cacao Tree Split radially by the Xylostroma of Armillaria Mellea. (See pages 9, 13).

[redacted]

PLATE V.

A.

B.

A. Sporophores of Armillaria Mellea on Cacao Tree.
B. Mature Sporophores of Armillaria Mellea on Cacao Tree.
(See pages 9 and 11).

PLATE VI.

Sporophores on Collar of a Cacao Tree. (See pages 5, 7).

PLATE VII.

Cluster of Sporophores of Armillaria Mellea on the Collar of a Cacao Tree
(See pages 9 & 11).

PLATE VIII.

A.

B.

Left : Frilly outgrowths of Xylostroma of Armillaria Mellea.
Right : Rhizomorphs of Armillaria Mellea on Butt of Cacao Tree.
(See pages 8 & 12).

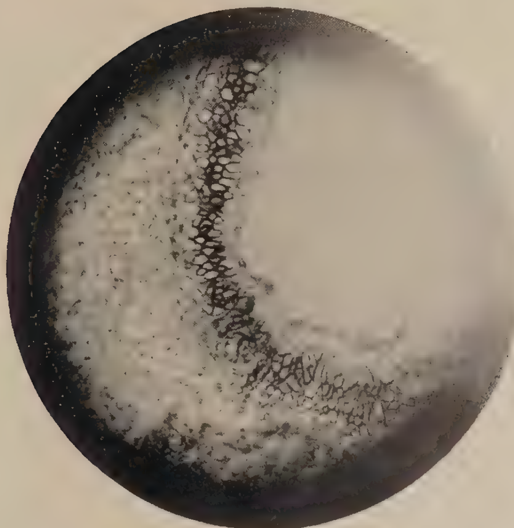
PLATE IX.

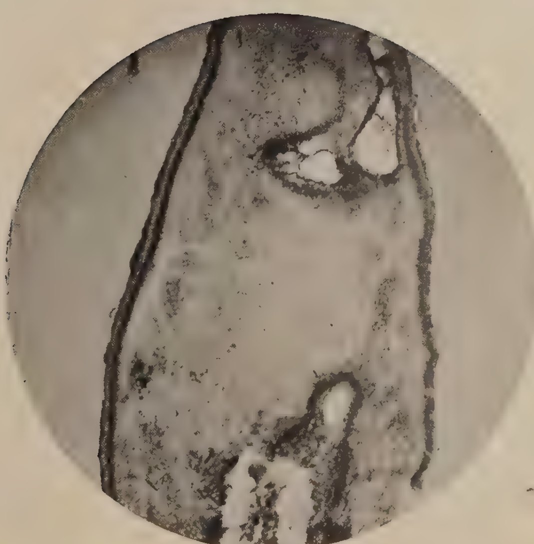
Rhizomorphs of Armillaria Mellea on a Cacao Tree. (See page 12).

PLATE X.

Rhizomorphs of Armillaria Mellea developed in Tube Culture.
(See page 12),

PLATE XI.





Tissues of the Xylostroma of Armillaria Mellea. (See page 11).

PLATE XII.

Transverse Section of Collar of a Cacao Tree shewing Radial Cracks caused by Armillaria Mellea.

PLATE XIII.

Collar of Cacao Tree attacked by Armillaria Mellea. (See pages 8, 9, 15 and 16.).

PLATE XIV.

Transverse Section of a Cacao Tree attacked by Armillaria Mellea.
(See pages 9, 12, 15 and 16).

PLATE XV.

Eriodendron Root infecting Cacao Trees with Armillaria Mellea.
(See pages 15 & 17).

PLATE XVI.

Contact-Infection of a Root of Cacao by an Eriodendron Root.
(See page 17).

PLATE XVII.

Area of a Cacao Farm destroyed by Armillaria Mellea. (See page 8.)

BULLETIN No. 6.

Department of Agriculture,

Gold Coast.

ECONOMIC SIGNIFICANCE OF CACAO POD DISEASES AND FACTORS DETERMINING THEIR INCIDENCE AND CONTROL.

BY

H. A. DADE, A.R.C.S.,
Mycologist.

Accra, January, 1927.

GOLD COAST.

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FOREWORD.

This bulletin gives the results of a careful investigation of the incidence of certain diseases of the chief crop of the Colony.

It will be seen that the investigation included such matters as the actual crop, the climatic conditions, &c., which have never been investigated in such detail before. I had numerous opportunities of inspecting the progress of the work and noticing the vast number of observations involved in the history of the fate of the pods, the actual information in the bulletin being perhaps merely a table of a few lines.

The results recorded are remarkable and indicate clearly the danger of relying on isolated casual observations. An investigation of this kind can be carried on only at one place at a time, but there is no reason to suppose that under similar conditions elsewhere the same results would not be found. The experience gained during the investigation, will be of considerable value in laying out other investigations elsewhere.

The bulletin is commended to the attention of all officers and others connected with or interested in the industry.

C. H. KNOWLES,

Director of Agriculture.

ACCRA, *24th December,* 1926.

CONTENTS.

THE ECONOMIC SIGNIFICANCE OF CACAO POD DISEASES, AND FACTORS DETERMINING THEIR INCIDENCE AND CONTROL.

By H. A Dade, A.R.C.S., *Mycologist.*

The first object of this investigation was the acquisition of definite information on the conditions which obtain in the native cultivation of cacao in the Gold Coast.

Such information is required in the consideration of economically sound means of control, and the results obtained are useful in this respect.

An analysis of the factors determining the degree of incidence of disease, and of environmental and meteorological conditions, has been made.

Up to the present our knowledge of the degree in which pod diseases cause loss, and their effect on the quality of the market product, has been extremely nebulous. Our only source of definite information has been the records of agricultural stations, which were primarily established for the demonstration of proper cultural methods and for the distribution of seed. These give little indication of the conditions obtaining in native cultivation, information as to which can be obtained only by personal observation, the majority of farmers being illiterates who keep no records whatever.

The economic practicability of modern methods of artificial control have also been investigated.

The work described in this bulletin must be regarded as a preliminary study only. The results obtained have suggested a wide field for future investigations.

The Anyinam district in Akyem Abuakwa was selected for this work because it was well known as an area in which loss from pod disease had been estimated as being very great. A temporary laboratory was installed, and the area was under continuous observation from May to December, 1926.

The writer wishes to express appreciation of the courtesy of the Anyinam farmers, who provided every facility for work on their farms.

SECTION I.

THE SITE OF THE INVESTIGATION.

Topography of the Anyinam District.

Anyinam is situated in the valley of the Birrim River, at elevations of from 550 to 600 feet above sea-level. The surrounding features are shown in the sketch map, Plate I.

The Birrim plains are very extensive and uniformly flat, intersected by the innumerable streams which feed the Birrim. The general level of the plain is about 600 feet above sea-level, eroded to from 500 to 550 feet in the river valleys. The plain is thickly clothed with forest, most of which is secondary, but which still contains a considerable proportion of trees of the virgin forest type.

The local features are confined to the configuration of the river bed. There is a more or less abrupt slope from the higher land to the alluvial flats which stretch for a varying distance on each side of the river. In places the transitional slope is very steep, and evidently represents the limit of recent lateral movement of the course of the river. A diagrammatic section through the river bed—Plate I—shows both types of slope. This feature is of interest in connection with the types of farms described later.

The flats are subject to periodical inundations which are produced during the seasonal rains by the vast quantities of water poured into the Birrim, which is at other times a sluggish stream of no great volume, by its tributaries from the Scarp and the Atewa range.

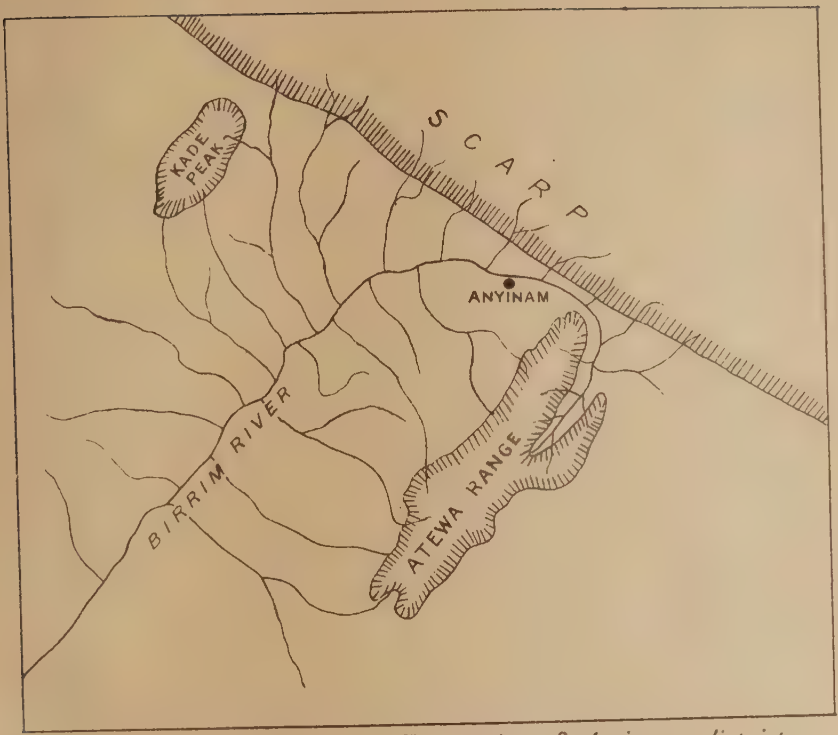
The shelter afforded by, and the rainfall associated with the surrounding hills are largely responsible for the excellent conditions for cacao cultivation which exist in this district.

Experimental Plots.

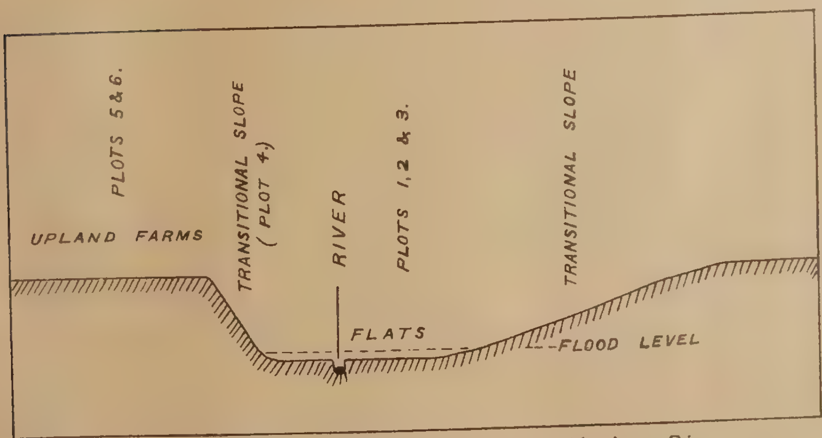
At the beginning of the investigation a number of plots of known area were marked out for various purposes. Of these, Nos. 1 to 6, each one-fifth of an acre in area, were used for the collection of data concerning production, incidence of disease and insect attack, etc.

These six plots were situated in definite regions, and their sites were selected as being typical. The two primary classes into which the farms in this district may be divided are "upland" and "riverside". A glance at Plate I. will make this clear. Plots 1, 2 and 3 were situated on the alluvial flats, 4 on a steep transition slope, 5 and 6 on the higher ground. A more detailed comparison of these plots is given in tabular form, Table 1, page 9.

PLATE I.



Sketch Map illustrating Topography of Anyinam district.



Diagrammatic Section through bed of Birrim River.

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TABLE 1.—COMPARISON OF PLOTS 1–6.

	Site.	Shade.	Inundation.	Drainage.	Ventil-ation.	Lateral Protection	Soil.	"Die-Back."	Humidity Group.	Height of Trees.	Age of Trees.	Plant-ing.
Plot 1	Riverside flats	Dense (excessive)	Annual and Periodical	Good	Bad	Good	No gravel, little sand, much clay and silt	Nil	High	20–22′	30	10′
2	,,	Very light (well adjusted)	,,	,,	Good	Good, rather poor on one side	,,	Little	Medium	15′	14	From nursery April 9′ 6″
3	,,	Dense (excessive)	,,	,,	Bad	Good	,,	Nil	High	22–24′	30	? 10′6″
4	Transition Slope	Very light (insufficient)	Partly affected	,,	Good	Poor	Much sand, some clay	Much	Low	15′	25	From nursery June 11′6″
5	Upland	Heavy (well adjusted)	Nil	,,	Poor	Good	Much sand, some silt little clay	Little	Medium	20′	23	At stake March 8′6″
6	Upland	Light (insufficient)	Nil	,,	Fair	Good	,,	Much	Low	18′	26	do. 10′

Farms on the riverside flats, which are continuous for miles on each bank of the river, are, though subject to floods, normally well drained. The river has very steep, almost vertical banks, and its normal level is from 5 to 10 feet below the level of the flats. During the inundations the river rises rapidly, until the flats are under water to a depth of up to four feet. But when the flood subsides, the river quickly sinks below the level, and the flood water drains off. These farms are remarkably free from canker and root diseases, which are common in farms on the banks of small streams, where the water table is always very close to the surface of the soil except during the harmattan (the dry season proper.) In such situations attack by *Armillaria mellea* frequently occurs and is particularly destructive.

A number of other typical plots were marked out for other purposes, *e.g.*, artificial control, insect observations.

General observations were carried on in farms throughout the district.

Methods of Observation.

The work in plots 1-6 involved frequent and regular examination of a large number of individual pods throughout their life. In these plots 543 trees and 5,169 pods were under close observation during the season.

The trees were labelled, and each pod, as it was set, was also labelled. Labels were cut out of thin sheet zinc such as is used for lining cases, and stamped with numbering punches. They were attached to the trees by means of copper tacks pushed into but not through the bark. Youths employed temporarily as observers visited each plot twice a week, and in note-books recorded for each pod insect or other damage, incidence and progress of disease, ripening and reaping.

The observations recorded by observers were checked by a Laboratory Attendant, who added further details to the records, and finally by the writer. Each day the data recorded were summarised and transferred to master records and to wall charts. Diagnoses of disease were in all cases made by the writer.

Only pods within the reach of the observers were labelled—that is, pods up to about seven feet from the ground. It was not possible to deal with pods at a greater height, and the data which were obtained from these plots apply only to trunk pods.

Pods in the upper part of the trees are in general set later than trunk pods, are somewhat smaller in average size, and are in conditions less favourable for the incidence of disease but more attractive to some sucking insects.

The Birrim Valley, in which Anyinam is situated, is climatically very suitable indeed for cacao, is the most suitable of all areas in the Eastern Province, and one of the most suitable in the whole of the Gold Coast, in which cacao is now grown.

The neighbouring hills, especially the Scarp, and the forest, exercise great influence on the humidity of the district, which is however, by no means free from the dangers of deforestation, though at present serious destruction is only just beginning. The institution of the reserves planned by the Forestry Department on the Scarp, on the Atewa range, and in the plain itself will do much to conserve rainfall. A more immediate danger to cacao cultivation is the local destruction of shade trees in the farms themselves.

Reference to PLATE II will show that, as is the case throughout the forest belt, there are two definite seasons during which rain falls, and two definite but unequal breaks during which dry conditions prevail.

In 1926 the June and July rains were below average, and the small break in August was pronounced. The usual inundation which is the result of the June and July rains was small, the river rising over its banks for only a few days, and to no appreciable height. September and November rains were rather above average.

The records which are chiefly of interest in connection with pod disease are those of relative humidity. Reference is made to these in the section on the factors determining the incidence of black pod disease. The records of rain, wind, temperature and sunshine are worth inspection, for they clearly demonstrate the effect of these factors on atmospheric humidity.

Effect of Rain.

In the rainfall graph Plate III a rough method of indicating the effect of rain has been tentatively adopted. The amount and distribution of rainfall are primarily the factors upon which soil humidity depends, but the physical character of the soil and other climatic factors determine the effect of rain.

The immediate effect of a fall is at its maximum at the time of the fall, which for the sake of argument we may regard as a moment. After the fall this effect decreases at a certain unknown rate. The rate itself decreases as time elapses, for, given constant atmospheric humidity, evaporation from the soil slows down according to the tension which is exerted in the soil owing to certain physical phenomena. The water content of the soil at any moment is there-

fore a function of the amount of effective fall and the time which has elapsed since the fall. The "effect" of rain is directly proportional to the amount of effective fall and inversely proportional to the time which has elapsed since the fall. We may express this by the following formula :—

$$E = \frac{F}{P}$$

where E represents the "effect" of rain at any moment,
F represents the fall in inches (effective),

P represents the period in days, including the day in which the fall occurred, which has elapsed since the fall.

The curve for this equation is a hyperbola, and the introduction of constants to represent the effect of the physical characters of the soil do not fundamentally affect the curve, but only its steepness.

The graphical representation of the effect of a single fall is therefore a vertical line proportional to the amount of the fall, from the peak of which the hyperbolic curve falls at a decreasing rate towards the ordinate.

The complete graphical record consists of a series of hyperbolas. Now the effect of a second fall must be added to the remaining effect of the previous fall. That is, the vertical line representing the second fall takes its origin from a point in the curve of effect of the previous fall, and not from the ordinate.

In Plate III is shown the graphical representation of the effect of rain alone on soil humidity at Anyinam during the period of this investigation. The black curve represents the effect of rain at any time, the red curve, which joins the minima, represents the minimum *sustained* effect.

(N.B. "Effective fall" means that portion of the actual fall which is absorbed by the soil. In a heavy fall much water is lost by surface drainage. In these records this loss has been roughly allowed for by deducting a percentage of heavy falls as follows :—

Falls over 5″ in a day—60% deducted.

Falls between 4 and 5″ in a day—50% deducted.

Falls between 3 and 4″ in a day—33.3% deducted.

Falls between 2 and 3″ in a day—25% deducted.)

SECTION II.

THE HOST PLANT—CACAO.

The Effect of the Environment on the Host.

It may not be out of place here to summarise briefly those environmental conditions which are favourable to the health of and production of fruit by cacao trees, for these conditions also have some influence on the incidence of disease.

In its natural state cacao is found in rain forest, and exhibits adaptedness to such conditions in its anatomy and physiology.

Cacao requires a high degree of constantly sustained humidity of soil and atmosphere, and soil containing a good supply of organic matter. It cannot tolerate a deficiency in either.

Suitability or unsuitability of environment is therefore determined by the relative significance of the factors which affect these requirements. Many different sets of conditions are satisfactory in this respect, for deficiencies due to the absence of some favourable factor may be adjusted by the presence of another.

Three factors alone are sufficient to preserve humidity and humus —an evenly distributed and adequate rainfall, deep soil (with good drainage), and shelter from wind and sun. Conversely humidity and humus are adversely affected by—a well-defined dry season, shallow soil (or badly drained deep soil), and exposure to wind and sun.

A deficiency in one favourable factor may be neutralised by another factor. Thus, well-drained deep soil will largely compensate for the effects of drought. Other factors may also occur, or be introduced, to make up for deficiencies. Examples of these are—overhead shade, lateral protection from wind, irrigation, consistently cloudy weather.

Shade and cloudy weather, when they exist in addition to conditions which are by themselves sufficiently favourable, inhibit the production of fruit, and it may then be necessary to remove the superfluous shade, or, in the case of a country where cloudy weather is a normal condition, to adjust other factors accordingly.

Irrigation has been mentioned, but is at present perhaps hardly practicable in the Gold Coast.

In the Gold Coast the principal adverse factor which occurs, and which cannot be controlled, is the very well-marked dry harmattan season, which lasts for about three months. This alone excludes many otherwise suitable areas from cacao cultivation, or alternatively necessitates an artificial adjustment of conditions.

The other adverse factor in this country is the extensive deforestation which has taken place, especially in the most highly developed areas, and which is now very seriously threatening the industry. The further growth of this factor can be controlled, but it has already proceeded so far that only the rapid introduction of compensating factors can save cacao from dying out in many areas.

In most of the Gold Coast cacao lands, shade is necessary, and only in a few very favoured situations can it be dispensed with. In Eastern Akyem, of which the site of the present work, Anyinam, is an example, very favourable conditions prevail over large areas, but even here the results of exposure are marked. Physiological die-back and severe insect attack are common in the poorly shaded upland farms (*e.g.*, plot 6) and similar symptoms may be found, in a less severe form, in lightly shaded riverside farms (*e.g.*, plot 2.) In all parts of the cacao areas the effects of the harmattan and deforestation are evident, and in very many districts it is becoming exceedingly difficult, or even impossible to fill vacancies.

Conditions of environment affect the incidence of disease in two ways. Conditions which are unfavourable to cacao reduce its resistance to attack by parasites or induce non-parasitic disease (i.e., physiological disorders), while conditions favourable to parasites augment their efficiency. Two examples of the former case are physiological die-back in exposed farms and the susceptibility to "Collar Crack" (caused by *Armillaria mellea* in water-logged soil.) Pod diseases offer abundant examples of the latter case.

Unfortunately conditions which are essential for the well-being of the host are sometimes equally favourable to the parasite. Thus a high degree of humidity is necessary for the successful infection of pods by *Phytophthora Faberi*, the principal pod parasite, and it is impossible to maintain by means of shade conditions of soil humidity which are suitable for growth of cacao without at the same time providing atmospheric conditions favourable, at least in a considerable degree, to attack by this fungus. It is only possible to attempt to reduce atmospheric humidity to the minimum compatible with the retention of harmattan protection sufficient for the well-being of the host. This may be easily overdone, and in any case this minimum by no means precludes all possibility of infection, although it reduces it to some extent. The only means of accomplishing this reduction in the Gold Coast is by adjusting shade and drainage. There are, however, few cases of the existence of superfluous shade in this country, for, in the vast majority of farms, shade is inadequate.

Excessive humidity in many cases is the result of the close planting which has been the rule in the Gold Coast. Tall, spindly trees, with densely packed foliage, have been produced, and the efficiency of ventilation has been thereby kept at a low level. For a time, the protection of the dense canopy thus formed serves the same purpose as shade, but once the continuity of the canopy is broken,

very serious exposure results. The natural removal of trees by root diseases or mechanical injury can been seen everywhere. In these places the exposure of the soil and desiccation which follows seriously affect neighbouring trees and render re-planting difficult. Such breaks in the canopy should be filled with quickly growing plants, but this practice is usually neglected by farmers, and the neighbouring trees frequently die, forming a large and ever-increasing vacant patch in the farm.

The re-modelling of closely planted and poorly shaded farms, in order to adjust conditions of humidity, presents great practical difficulties. It will be obvious that reducing the number of trees to the acre would introduce exposure, and until practical experiments on this problem have been performed it is not possible to recommend any remedy for this condition.

In native cultivation generally, therefore, it is not possible to control excessive humidity by the adjustment of environmental factors. But there is very much room for improvement in factors affecting the essential physiological requirements of cacao, thereby increasing its vigour and therefore its resistance to attack.

Periodicity–Production and Ripening.

The variety of cacao in common cultivation in the Gold Coast is yellow Amelonado, originally impored from San Thomé and Fernando Po. Other varieties are not so successful in this country, and are found only in small plots on agricultural stations.

Two crops a year are produced—the main crop, which is reaped from September to December, and the mid-season crop, reaped from about May to June. The latter is small compared with the main crop.

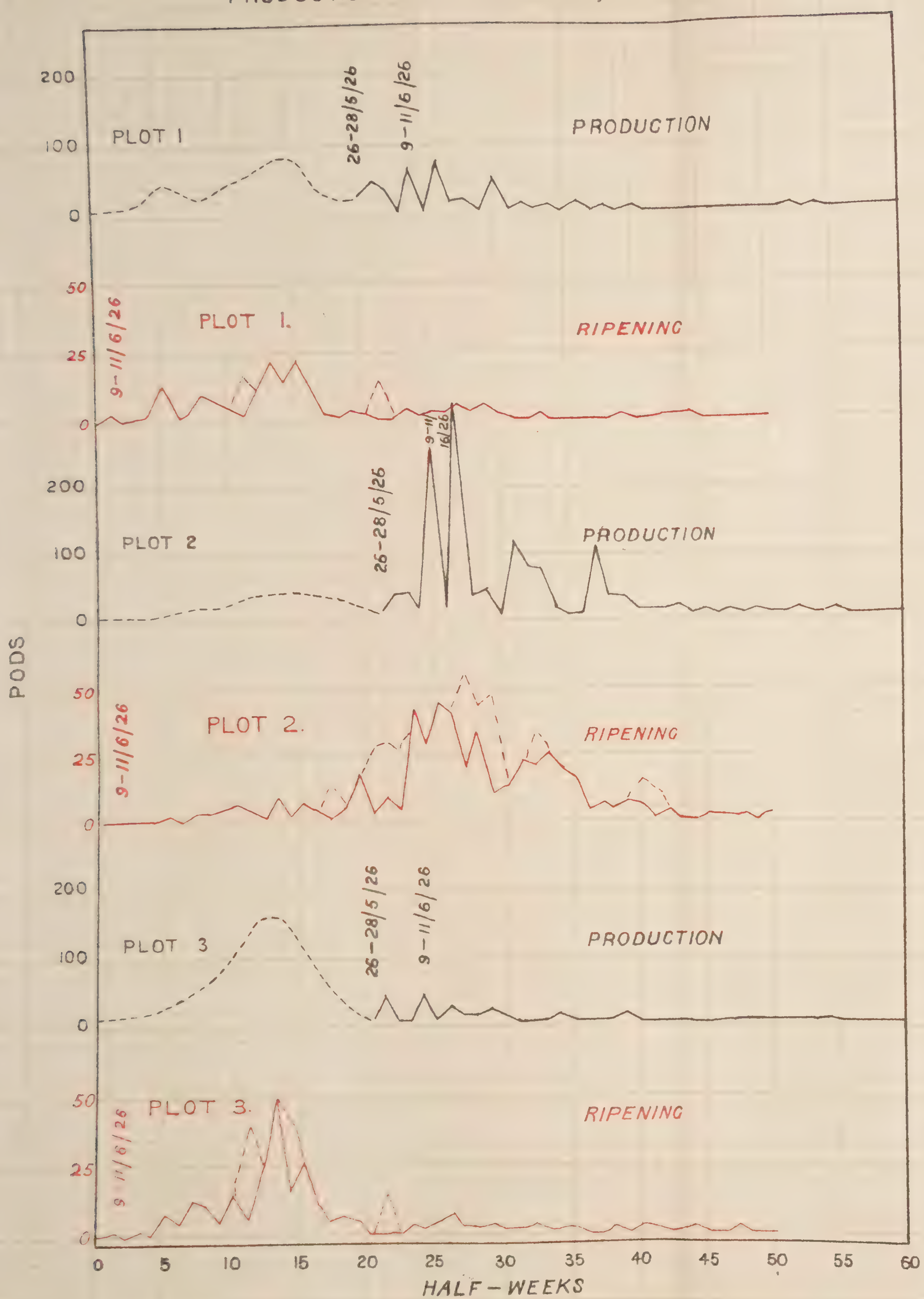
G. G. Auchinleck, in an analysis of station records, (2) shows that there is a probable relation between the periodicity of fruiting and the seasonal rains. He also draws attention to the interesting fact that the mid-season crop diminishes and tends to disappear as the age of the trees increases.

It seems probable that this diminution in the mid-season crop is universal throughout the country. Cocoa buyers report that their mid-season purchases are steadily decreasing. There is no corresponding decrease in the main crop, which increases up to a certain point and then remains steady for a period depending on nutritional conditions, etc.

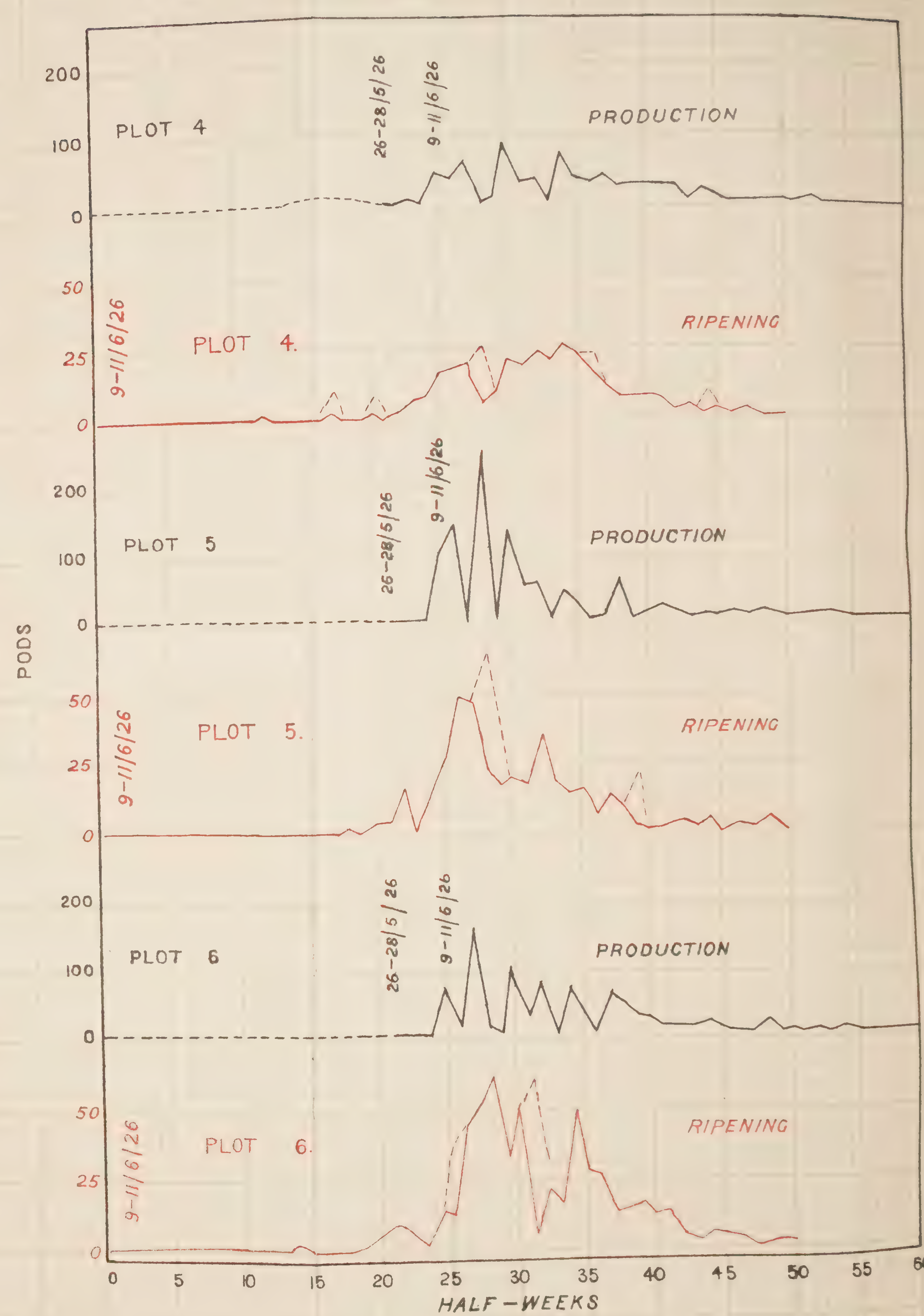
The statements of farmers, and the observations of the writer in the Anyinam district are consistently in agreement with Auchinleck's statement with regard to this phenomenon. In all cases farmers report an originally normal mid-season crop which has now become reduced to a negligible size. They either do not trouble to reap it, or use a few pods for seed.

PLATE IV

PRODUCTION AND RIPENING, PLOTS 1-3.



PRODUCTION AND RIPENING, PLOTS 4-6.



An outstanding fact is the very early production of main crop in farms on the riverside flats in this district. The main crop in farms on the higher ground, of which plots 5 and 6 are typical, ripens at the time which is normal throughout the country. The principal ripening of the crop in riverside farms, however, occurs about seven weeks earlier. At the beginning of this season's work this fact was not known, and the author arrived in time to begin plot records towards the end of May. Consequently the production graphs, Plate IV, are not complete. There were already large numbers of pods formed on Plots 1 and 3 and some on 2. The ripening graphs, however, indicate approximately the period at which the flowers appeared.

In these production and ripening graphs two date scales are indicated—showing dates of recording " setting " and of recording ripening. Pods were labelled and their individual records begun when they reached the length of three and a half inches, which was found, by a minor experiment, to correspond to an age of approximately eleven weeks. This deliberate delay in taking pods into record was designed to allow for the natural discarding of surplus fruit, which takes place up to, but very seldom after, this age. Attack by parasitic fungi on pods below this age seems to be very rare.

Pods were therefore regarded as being definitely set for crop at the age of approximately eleven weeks. The date scale for the recording of setting therefore is eleven weeks later than the actual date of setting from flower.

The ripening curve has been laterally displaced to bring into coincidence the peaks of this curve with the peaks of the corresponding production curve. This displacement represents a period of $11\frac{1}{2}$ or 12 weeks, according to the plot. So that the period between actual ripening and setting was this year, 1926, approximately $22\frac{1}{2}$ to 23 weeks.

In production curves, the broken line indicates the probable production which took place before observation was begun. In the ripening curves the broken line indicates an estimated allowance for discrepancies in these curves which are due to premature reapings which took place at these times.

Plots 1 and 3 are typical of the great majority of riverside farms. It will be seen that, according to the incidence of ripening, the majority of the fruit must have been set in these farms approximately at the end of February, while a good deal was set between then and the middle of January. On typical upland plots the setting of fruit did not begin until the middle of March, and the majority was set in early April.

This remarkably early production on the typical heavily shaded, periodically flooded riverside plots is undoubtedly due to the relatively high humidity of soil and atmosphere in this situation during

the harmattan season, when the drought which is so considerably felt elsewhere, and indicated by the pronounced physiological die-back of the upper twigs, is in these farms much less severe. That a high degree of humidity exists at this season is proved by the fact that the trees in some of the farms were actually planted, as seed, during the harmattan. The evidence of farmers shows that the early production is quite normal, and in 1926 it was not accelerated, for the preceding harmattan drought was rather more severe than usual, and this would tend rather to delay production.

Plots 2 and 4 are of interest as throwing light on the cause of this phenomenon. Plot 2 is situated on the flats and is subject to exactly the same conditions as plots 1 and 3 except that it is very lightly shaded. The relation of this condition to humidity of the soil and atmosphere during the harmattan is obvious. Plot 4 is nearly contiguous with the flats farms, but is on a steep transition slope only affected by floods at its lower edge. It is very lightly shaded and rather exposed, and shows very little signs of early production. Plot 2 however shows a tendency to early production due no doubt to its sharing some of the characteristics of the more densely shaded farms on the flats.

In the alluvial flats by the Birrim we find one of the very few areas where the effect of the harmattan is not severe. The trees are not so dependent on the advent of the rains for the resumption of their periodical activity, which begins earlier.

Production per acre.

It is extremely difficult to obtain from farmers reliable details of production. They either keep no records or are reluctant to give information.

Production on plots representative of the main types of farms in the Anyinam district was estimated by counting pods produced on all parts of the tree and converting this figure to pounds of dry cocoa per acre. This was done by weighing the raw cocoa from 500 pods and weighing again after fermentation and drying. This was repeated on several occasions in order to obtain fairly accurate data on the different farms at different parts of the season.

In the cases of plots 1-4, some of the pods were omitted from the count, having been previously reaped. In plots 5 and 6 the count was made before all the crop had been set. In all cases therefore production is somewhat underestimated, and this under-estimation has been accentuated because the largest number of pods per pound of dry cocoa found by experiment has been used in each case. In the case of plot 5 it was possible to verify the estimate by accurate records supplied by the owner.

Reference to the Section on the effect of disease on the prepared product will show that on the average only 4 per cent of the crop was lost. This has not been allowed for in the estimated production, which is shown in Table 2.

TABLE 2.

YIELDS PER ACRE ON NATIVE FARMS, ANYINAM, 1926.

Plot.	Trees per acre.	Average planting distance.	Pods per acre produced.	Average pods per lb. dry cocoa.	Estimated dry cocoa per acre.	Farmer's record.
1	440	10′	11,835	8	13.2 cwt or 1,479 lbs.	—
2	500	9′ 6″	13,835	10	12.3 cwt or 1,384 lbs.	—
3	400	10′ 6″	7,535	8	8.4 cwt or 942 lbs.	—
4	335	11′ 6″	16,715	10	14.9 cwt or 1,672 lbs.	
5	580	8′ 6″	13,665	10	12.2 cwt or 1,367 lbs.	13.9 cwt. or 1,555 lbs.
6	435	10	11,645	10	10.4 cwt or 1,165 lbs.	
			Average ..	..	11.0 cwt. or 1,335 lbs.	

Previous estimates, which were nothing more than guesses, and of no real value, have ranged from two to six hundred pounds per acre. The present estimates are based on actual counts, are verified in one case, and tend to be low.

Reference to Bulletin No. 4 of the Department of Agriculture—"Yields of Cacao on Experiment Stations" by G. G. Auchinleck, (2)—will show that even the best stations have rarely produced records comparable with these yields on native farms. The average for all stations given in the bulletin quoted above is 595 pounds of dry cacao per acre, but this does not provide a fair basis for comparison, for some of the stations are in situations not very favourable for cacao cultivation, while the Birrim Valley is one of the best cacao areas. Moreover, on agricultural stations loss from disease is given as from 3 to 20 per cent. Though incidence of disease is less on stations, owing to good management, than it is in native farms, a larger percentage of the crop is "lost" because attention is given to the quality of the product and a good deal of damaged cocoa is discarded.

Nevertheless, these yields from native farms are much higher than was expected. It may be of interest to summarise the main differences between station and native methods.

In agricultural stations the planting distances in use are 15′, 12′, 10′ and 8′ x 15′. The highest yields have been obtained from plots planted at 15′. The plots are kept weeded and in a sanitary condition, and are in some cases mulched. The growth of the trees has been controlled in order to produce an economical form, and the trees themselves have been cared for surgically. Shade, lateral protection, ventilation and drainage have been carefully adjusted.

In native farms trees usually are very closely and irregularly planted. The average planting distances shown in Table 2 are the result very often of the process of the survival of the fittest, many "vacancies" having occurred. Farms are cutlassed in time to facilitate reaping. No form of manuring is practised, and sanitation is completely neglected. Trees are allowed to grow into the form they naturally assume in close planting, and are not pruned. They receive no surgical attention whatever. No attention is paid to the requirements of the crop in respect of shade, lateral protection, ventilation and drainage, except that a few of the original bush trees are usually allowed to remain for shade.

A number of trials were made to find the average number of pods per pound of dry cocoa in different farms. This varied from 6.9 to 10. In agricultural stations the highest number recorded is 8.6, the lowest 20.6.

SECTION III.

FACTORS DETERMINING THE INCIDENCE OF BLACK POD DISEASE.

In this investigation an attempt has been made to study the various factors which determine the degree of incidence of infection by analysing results in such a way as to isolate, as far as possible, their separate effects.

Humidity and the Presence of Diseased Pods.

Data indicating the effect of these two factors are shown in the form of a graph in Plate VI, and they may be conveniently considered together. These data were derived from Plots 1 and 3. Similar records were obtained for other plots, with similar results, but that for the most humid plots is most instructive and that only is shown.

The lowest curve, in the form of a frequency histogram, with a column for each half-week period in which observations were recorded, represents the percentage of hitherto healthy pods which first exhibited symptoms of disease during each half-week. The first visible symptom of disease is the familiar brown discolouration spreading from the point of infection.

The topmost curve represents in a similar manner the percentage of the pod population actually on the trees which was diseased on each occasion of observation. It will be seen that this curve steadily rises until the occurrence of a large reaping suddenly reduces the percentage of the population which is diseased. This is because the farmer on these occasions removes all diseased pods, whether ripe, full-grown, or not, in order to save the beans. The curve then begins to rise again.

The two intermediate curves represent the Relative Humidity in these farms. This was recorded twice a day at 7.30 a.m and 2.15 p.m. In the absence of a continuously recording instrument it is believed that the readings taken at these times are fairly representative of conditions of humidity obtaining throughout the night and the day respectively. On a very few occasions the day record was vitiated by showers, which have occurred only very infrequently at the actual time chosen for the day reading, significant rain having fallen rather uniformly in the evenings. This has not materially affected the value of the readings.

It will be seen that the day curve, as may be expected, fluctuates to a much greater extent than the night curve, which only occasionally falls below 95 per cent saturation.

The principal disease, "Black Pod", is caused by a fungus, *Phytophthora Faberi*, Maub., for infection by which a high degree of humidity is necessary. The sporangia of this fungus are stimulated to germinate or to liberate zoospores in the presence of a film of moisture on the surface on which they lie, and this also permits the migration of the freely swimming zoospores. In the evening, at sunset, the fall in temperature causes the saturation point to be reached, and condensation ensues. The deposited water remains until the Relative Humidity falls owing to the rise of temperature next day, or to other causes, when it begins to evaporate.

During the night, therefore, conditions are almost uniformly satisfactory for infection during the period under consideration. But Relative Humidity is consistently lower, and sometimes very low, during the day. A lowering of Relative Humidity during the day correspondingly reduces the total time available during which infections can take place. If a high Relative Humidity is sustained throughout the day the period available for infection becomes continuous. Such humid conditions also stimulate the production of spore-masses on diseased pods and increase chances of dissemination. If the night humidity does not, and the day humidity does, fluctuate considerably, we should expect to find that the latter condition is the principally significant one, and this is so, but the effect of the less obvious fluctuations of the night curve must not be over-looked.

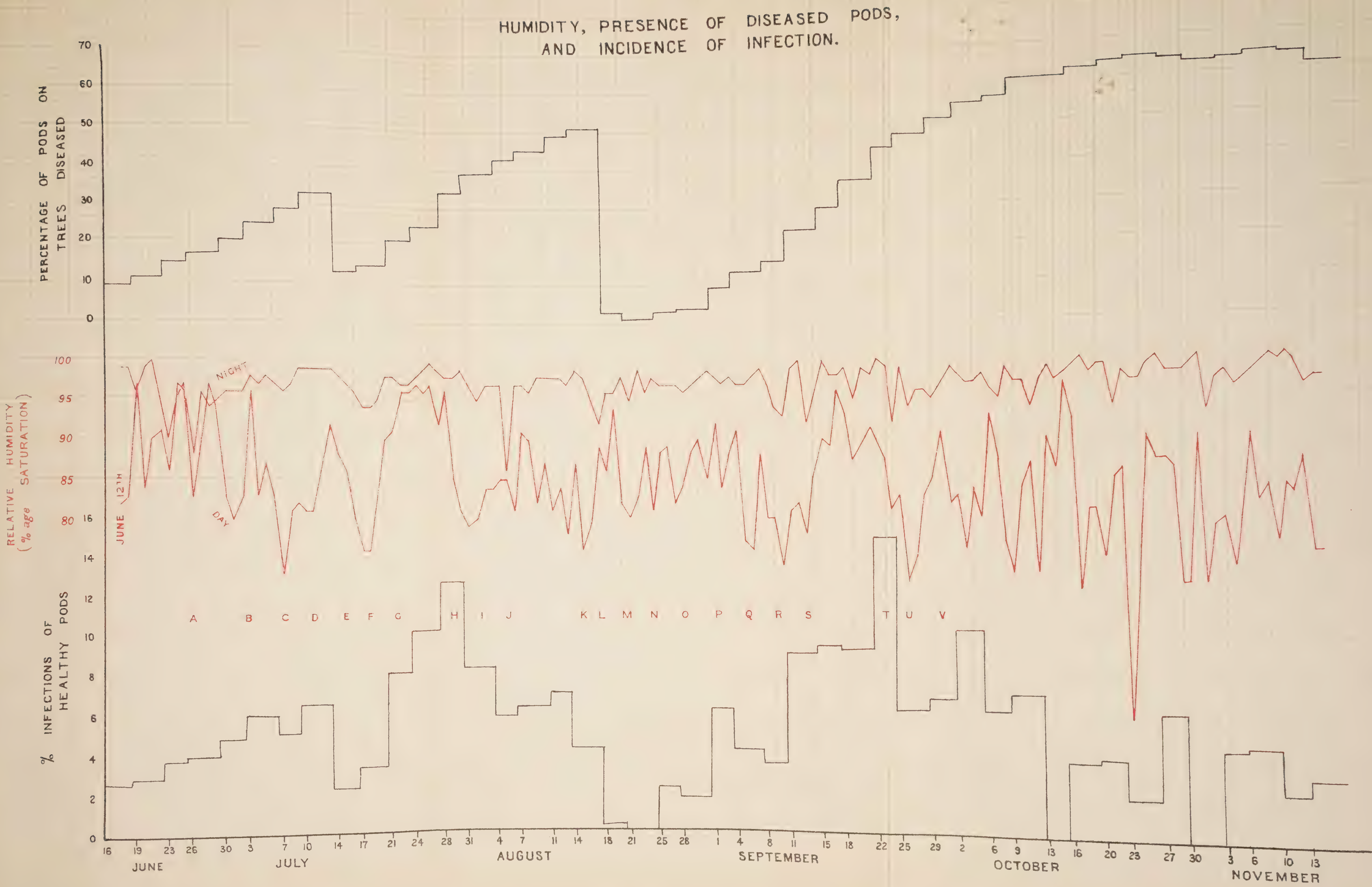
The recording of incidence of disease by the discolouration symptom, the only possible criterion, introduces an error of fairly definite limits. Discolouration does not occur immediately upon infection, but after a delay the duration of which depends upon the nature of the infection. In the laboratory and in field tests it is found that discolouration is exhibited about two or three days after inoculation through a wound, which in the case of inoculations which are not accompanied by wounding, up to seven or eight days may elapse before the discolouration appears.

In farms both forms of infections occur, wounding being of common occurrence through insect and mechanical agencies.

This delay must therefore be taken into account, and this is done in Plate VI by setting the humidity-curves forward for an arbitrary period of five days, roughly the mean period which elapses between infections of both kinds and the appearance of discolouration.

The heavy June rains fell off towards the end of June, and a rather dry period ensued until the middle of July. Heavy rain fell again until the end of July. Throughout August the short dry season intervened and heavy rain again occurred in September. Humidity varied accordingly, and the curves show two distinct periods of low, and two of high, humidity. The peaks of the incidence curve coincide with the periods of high humidity H and T, while incidence falls off markedly during the dry periods C, F, I—J—K—N—O—P—Q, U. The lesser variations of each curve

PLATE VI



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also correspond. The curve of the product of the day and night humidities shows a more distinct resemblance to the incidence curve, but has been omitted in order to simplify the diagram.

In reading these curves the effect of the considerable fluctuations in the night curve must not be disregarded. Thus, at A, C, F, I, O, S, U the effect of day humidity is enhanced by the night humidity, while at L for example the drop in night humidity neutralises the effect of the rise in day humidity.

Examining the effect of the presence of diseased pods in the population, it will be seen that in the early part of the records the incidence curve follows the diseased pods curve, and it does so again from F to H and from N to T. But from H to L, from P to R, and from T to V the apparent effect of the increasing diseased population is overcome by the falling humidity. At times therefore when the atmospheric humidity is low the presence of centres of infection in the form of diseased pods loses its significance.

It appears from these data that atmospheric humidity is probably the most important factor affecting the incidence of "black pod" disease. This is confirmed by the results obtained in the study of other factors, most of which are controlled by the key factor of humidity.

(Relative Humidity readings taken in a clearing throughout the period were naturally much lower. For example, during the wet spell G—H the highest reading recorded for day humidity was 88 per cent saturation.)

Transmission of Disease.

Air currents as agents of distribution may be considered as of negligible importance. The air in cocoa farms is normally very still, owing to the obstruction offered by the surrounding bush and by the cacao trees themselves. Viable sporangia cling rather closely to the host and are not very easily dislodged by air-currents.

Insects are probably mainly responsible for the transportation of spores from one tree to another. Cacao trees are visited by large numbers of insects of many kinds, which walk over the pods. Insects removed from trees were allowed to walk over the surface of the medium in sterile culture tubes, and cultures of *Phytophthora Faberi* were obtained—mixed, of course, with numerous saprophytes. Insects are therefore definitely able to carry spores from one tree to another. Several trees were enclosed in netting in order to attempt to find out whether the exclusion of insects had any effect on the degree of incidence of disease. This experiment failed on account of the high relative humidity which obtained inside the nets, owing to the latter becoming soaked with rain and dew, and which resulted in a greater percentage of infections than in control trees.

Man undoubtedly plays a part in transmission, at least in regard to trunk pods. Trees bordering narrow, frequented tracks show a higher proportion of infections than others, and this is no doubt due to contact between pods and the clothing of passers-by.

Local Transmission from one pod to another on the same tree is partly effected by insects. Two other agents are well-known, and account for a very large proportion of infections. These are :—

Contact and Drip, that is, contact with a diseased pod, and drops of water containing zoospores or sporangia which fall from a diseased pod. An analysis of the significance of these factors has been made and is shown in Tables 3—5.

TABLE 3.

P. Faberi. INFECTIONS BY CONTACT WITH DISEASED PODS.

Count B. 2054 infections.

Plot.	Contact infections with no injury.	Contact infections with injury.	Total contact infections.	Total infections.	Percentage of total associated with contact.
1	120	9	129	471	27.5
2	106	17	123	503	24.4
3	55	13	68	241	28.2
4	33	12	45	172	26.2
5	101	14	115	475	24.2
6	36	11	47	192	24.5
Totals	451 or 21.9%	76 or 3.7%	527 or 25.6%	2,054 or 100.0%	

TABLE 4.

P. Faberi. INFECTIONS BY DRIP FROM DISEASED PODS.

Count C. 2054 infections.

Plot.	Drip infections with no injury.	Drip infections with injury.	Total Drip infections.	Total infections.	Percentage of total associated with drip.
1	78	11	89	471	18.9
2	52	7	59	503	11.7
3	57	10	67	241	27.8
4	11	2	13	172	7.6
5	39	9	48	475	10.1
6	11	nil	11	192	5.7
Totals	248 or 12%	39 or 1.9%	287 or 13.9%	2,054 or 100.0%	

TABLE 5.

P. Faberi. HUMIDITY, TOTAL INFECTIONS, AND DRIP INFECTIONS.

Count D. 5,169 pods, 2,054 infections.

Plot.	Total pods recorded.	Total infections recorded.	Percentage of total pods infected.	Percentage of total infections associated with drip.
3	568	241	42.6	27.8
1	752	471	62.6	18.9
2	1,395	503	36.1	11.7
5	978	475	48.6	10.1
4	632	172	27.2	7.6
6	844	192	22.9	5.7

In the case of *contact* it will be seen (Table 3) that 25.6 per cent of the infections studied were associated with contact, and they were undoubtedly caused by it. The drip factor does not complicate this analysis, for the fungus is already conveyed to the pod. Injury has been considered along with contact, but the figures show that it is of questionable importance, as might be expected, for *Phytophthora Faberi,* being a true and efficient parasite, is not dependent upon wounds for entry, although in some cases wounds facilitate and certainly accelerate infection. In the case of contact infections, however, other conditions are so favourable (see under " site of infection, " below) that injury may be regarded as of no importance when contact occurs.

It will be seen that the percentage of the total infections which are associated with contact is very constant for all plots. This might be expected, for contact depends upon the morphology of the host—the production of pods crowded closely together, especially on the trunk,—a constant factor.

Contact is not complicated by the factor of diseased cushions, for in every case recorded contact-infections showed discolouration radiating from the point of contact. Very few cases of double infections occur. The pod tissues are invaded so rapidly by *P. Faberi* that double infections are only apparent when they occur simultaneously. Only 4 pods showing double infections were recorded out of over 2,000 infections which were closely observed.

Evidently the contact factor is of very great importance in the incidence and local spread of pod disease.

Drip is of less importance. Table 4 shows that 13.9 per cent of the total infections were associated with drip. As in the case of contact, injury is the only other relevant factor, but the data indicate that here again it is of minor importance. Drip is closely connected with the humidity factor (Table 5,) and this connetion is referred to again under " site of infection."

Site of Infection.—Morphological Factors.

Table 6 shows the proportions of infections by *P. Faberi* associated with contact with, and drip from, diseased pods, with injury, and with pods affected by none of these factors, all with reference to the site of infection. These data are of considerable interest.

Of the total infections, grouped according to site only, 65.2 per cent were proximal, 24.0 per cent lateral and 10.8 per cent distal. When these infections are classified further into those associated with contact, drip, and injury, the percentages occurring in the site groups are of very much the same order. Table 6 (2.)

TABLE 6.

SITE OF INFECTION.

Count A. 2111 infections.

1. General Percentages.

Site.	Injury.	Drip from diseased pods.	Contact with diseased pods.	No other factors.	Total infections.
Prox.	14.8	9.2	17.2	24.0	65.2
Lat.	8.0	2.4	6.3	7.3	24.0
Dist.	3.2	1.4	1.3	4.9	10.8
Totals	26.0	13.0	24.8	36.2	100.0

2. Class Percentages.

Site.	Injury.	Drip from diseased pods.	Contact with diseased pods.	No other factors.	Total infections.
Prox.	57.0	70.0	69.3	65.8	65.2
Lat.	31.0	19.2	25.3	20.6	24.0
Dist.	12.0	10.8	5.4	13.6	10.8
	100.0	100.0	100.0	100.0	100.0

3. Group Percentages.

Site.	Injury.	Drip from diseased pods.	Contact with diseased pods.	No other factors.	
Prox.	22.9	14.1	26.4	36.6	100
Lat.	33.2	10.3	25.7	30.8	100
Dist.	28.6	13.2	12.3	45.9	100

This clearly indicates that, quite independently of other factors affecting incidence, conditions favouring infection occur in a very different degree in the various regions of the pod. Obviously they are most favourable at the proximal end, and least favourable at the distal end.

We have seen that *P. Faberi* requires a high degree of sustained humidity in order to successfully carry out infection. In addition to the relative humidity of the atmosphere, the morphology of the host is responsible for the setting up of local concentrations of humidity by means of the retention of drops of water by surface tension.

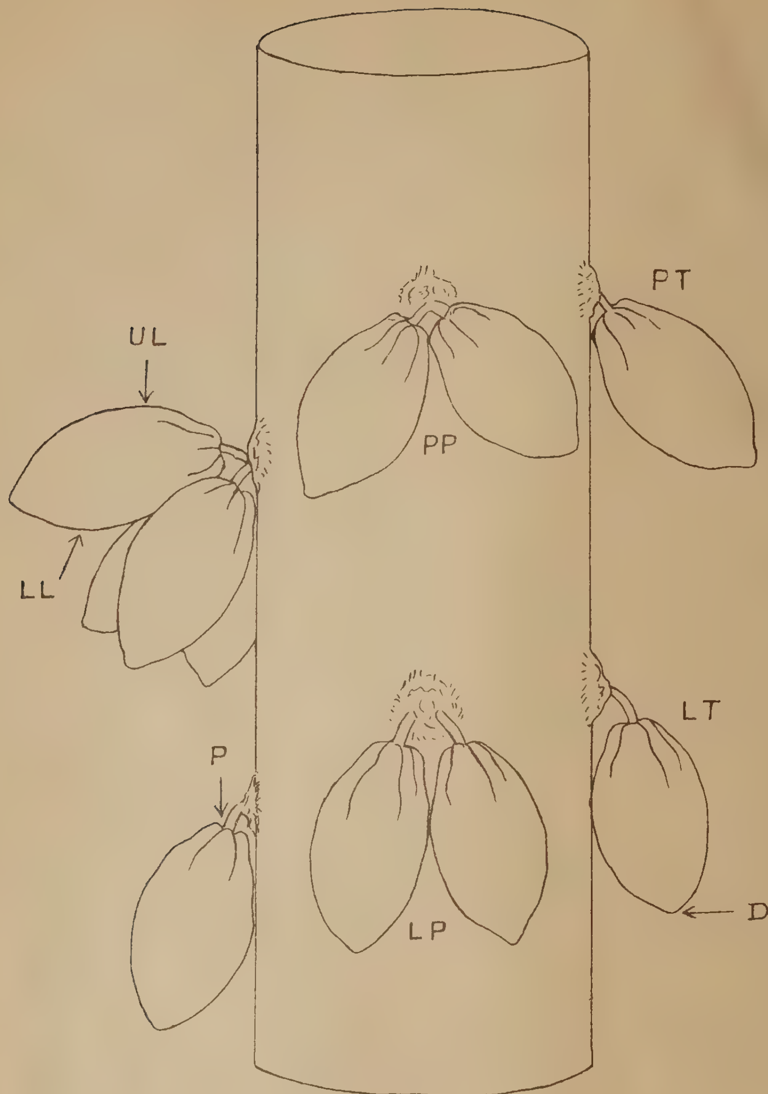
During rain and heavy dew, water streams down the branches and trunk, and drips from the foliage. Moisture is retained—(i) very frequently in the annular depression at the proximal end of the pod, where the insertion of the peduncle occurs; (ii) at points of contract,—usually proximal, sometimes lateral, never (?) distal,—between pods and the trunk or branch; (iii) at the points of contact—frequently proximal, often lateral, seldom distal—between two pods; (iv) occasionally on the upper lateral or lower lateral surfaces of pods which are forced into a more or less horizontal position; (v) occasionally on the distal ends of pods in which the drip point is blunt. See Plate VII.

This retention of moisture occurs most commonly in the proximal region, and least commonly in the distal region, and having regard to the fact that humidity is the key factor in infection by *P. Faberi*, there is no doubt that this explains the remarkably constant proportions of infections which occur in the different regions of the pod.

The degree of atmospheric humidity, by determining the rate of evaporation, of course determines the actual time during which these drops of water persist. In those periods which occur frequently during the night, and sometimes in the day, during which complete saturation occurs, a film of moisture probably exists over the complete surface of the pod, and at this time conditions are at the optimum for infection. These periods however are of short duration when compared with the length of time during which drops held by surface tension exist. It is probable that the great majority of infections occur in the neighbourhood of these accumulations of moisture.

Contact between pod and trunk and pod and pod have a further significance. The neighbourhood of such points is the favourite site of entry by pod-borers. The relative movement which takes place moreover causes slight abrasions. These injuries further facilitate infection.

PLATE VII



POINTS AT WHICH MOISTURE IS RETAINED

BY SURFACE TENSION.

PT - Between proximal end of pod and trunk.
LT - Between lateral surface of pod and trunk.
PP - Between proximal ends of pods.
LP - Between lateral surfaces of pods.
D - At distal end of. pod.
UL - On upper lateral surface of pod.
LL - On lower lateral surface of pod.
P - In annular depression at proximal end.

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Infection by drip from diseased pods is dependent for its success upon the retention of the spore-containing moisture for a sufficient time. Both this and the foregoing remarks are illustrated by Table 5 (page 25) in which plots are grouped according to their humidity, and the percentages of total incidence, and of drip infections, shown.

Returning to Table 6, (3) (site) a few other points are worthy of comment. Of the proximal infections alone, the greatest number were not associated with injury or with drip from, and contact with, diseased pods. This may be due, not only to the superior facilities which exist in this region for the retention of moisture, but also to infection from diseased cushions. This phenomenon is referred to again below—its value as a factor in incidence is not yet determined, but it is possibly of some considerable importance. In fact, these proximal infections which are not associated with drip, contact or injury account for the largest percentage of all types of infection.

The lateral region is the most extensive and the most exposed to mechanical injury and to insect attack, and it is therefore not surprising to find that in this group the largest percentage of infections are associated with injury. (Table 6, 3).

Next in importance is " no other factors ",—the lateral region is subject to considerable retention of moisture by contact with trunk and other pods.

The distal region is least exposed to infection by all agencies. In this group the percentage of infections associated with contact with diseased pods is the smallest, and this corresponds with the fact that the distal end of the pod is least likely to be in contact with other pods. The largest percentage of distal infections is not associated with other factors, and this is probably due to the retention of water at the drip point, which in the Amelonado variety is rather blunt and often not very efficient. The most commonly seen distal infection is characterised by a geometrically regular discolouration which indicates that infection took place exactly at the drip point.

Possibility of Control by Modification of the Host.

The world having produced a Burbank, it is perhaps not mere idle speculation to remark that the data gathered in this investigation suggest how the host itself might be induced to co-operate in the solution of the problem of controlling pod disease, particularly when we consider how practical and economic conditions which exist, especially in the Gold Coast cacao industry, render control by the ordinary methods very difficult.

The production of a strain of cacao exhibiting certain peculiarities, the growth of which were artificially controlled, would do much towards reducing the incidence of disease.

Such an ideal strain would be characterised by the elimination of the peduncular depression, by more numerous cushions—in order to avoid the frequent contacts which result from the production of several pods on one cushion—and by a sharp drip-point.

Control of habit by pruning would include the formation of a very short trunk and a few large main limbs, on which the setting of pods would be limited as far as possible to the lower sides, in order to avoid contact between bark and pod.

In the case of such trees the retention of moisture by surface tension, and the chances of drip and contact infections, would be greatly reduced, and probably at least 50 per cent of the infections which occur in the present type of tree would be obviated.

Injury.

Cacao pods are very commonly wounded. About 40 per cent of the total pods kept under observation in this investigation were injured. Insects are responsible for the majority of the damage, but some is caused by man in his use of cutlasses and reaping-hooks. Damage facilitates the entry of parasites such as *Phytophthora Faberi,* which otherwise have to penetrate the epidermis before they can reach the tissues which provide them with nutrition. The process of penetration occupies some time, and if it is interrupted by, for example, a sudden drop in humidity, before it has progressed sufficiently to render the infection-hypha independent of the outside spore-body, the infection may fail. In the case of wounds, the nutritive tissues are exposed, and infection proceeds rapidly if the host has not yet had time to form a protective cork-layer. Infection is further assisted by the exuded sap and mucilage at the wound, and also by water which, though normally shed by the sound epidermis, is retained at the site of wounds.

Analyses of the injury factor produces interesting results. In Table 7, 1, (page 33) we see that in the humid plots there is a greater percentage of infection in injured pods than in uninjured pods. In plots 1 and 3 all the pods under observation were uniformly subjected to high humidity. In these plots we see that injury has a definite significance.

In the drier plots, 4 and 6, we find that there was actually a smaller percentage of infection in wounded pods than there was in uninjured pods. This indicates that in the drier plots conditions are in some way more favourable to infection in the case of uninjured pods than they are in that of injured pods. A detailed analysis of the various types of injury explains this apparently paradoxical result.

Table 7, 3, shows the percentage of total injury, (excluding that by unidentified insects, about which we know nothing,) caused by the various agents. It will be seen that the predominating types are different in the various plots. *Helopeltis,* borer, and mechanical (man-inflicted) injury are predominant in plots 1, 2 and 3, while thrips, *Helopeltis,* mechanical injury, and in one case *Sahlbergella,* predominate in plots 4, 5 and 6.

Injury by thrips occurs principally upon pods in very exposed situations—*i.e.,* on the sides of roads and clearings, or throughout farms which require, but are deficient in, shade and lateral protection, and here a high degree of relative humidity is sustained only for short periods, and humidity generally is low. In such situations, humidity, the key factor in incidence of disease, is most unfavourable for infection, and this undoubtedly explains the apparently contradictory results in Table 7, 1.

On the other hand, mechanical injury is not determined by humidity, while borer attack is perhaps slightly favoured by high humidity, and these types of injury are of a more serious nature than are the small punctures made by sucking insects. This is indicated by the high percentage of infections in pods damaged by borers and mechanical injury, as shown in Table 7, 2.

Helopeltis damage is also found more commonly in exposed situations, but the occurrence of *Sahlbergella*, is, it is believed, principally affected by other factors. (3)

Returning to Table 7, 1, we find that the percentage of infection in injured pods decreases as we pass from high to low humidity groups. The humidity factor is as we have seen the key factor in incidence, and, as in the case of drip infections, it determines the relative significance of the injury factor.

This is true of all types of injury, for in Table 7, 2, we find the same gradation in percentage of infection in the humidity groups for each type where we have a sufficient total number of infections to obtain figures of any use. In the case of scale-insects and *Sahlbergella* the total numbers of infections recorded are too small to be of any value, and these types must be excluded from consideration for this reason. We may also exclude unidentified insects, as in the absence of other details we can give no useful information.

It will be apparent that the significance of injury cannot be definitely estimated—it depends upon the type of injury which occurs, but mainly, apparently, upon humidity.

In exposed farms there are usually greater numbers of insects which damage pods than in humid farms, but the greater amount of damage is more than neutralised, so far as infection is concerned, by the lower value of the humidity factor.

In farms where humidity is excessive there is less insect damage than elsewhere, but a greater percentage of wounds is followed by infection.

The medium humidity group farms, as exemplified by plots 2 and 5, are those in which humidity is at the minimum compatible with conditions which are suitable for the host, while it is not excessive from the point of view of incidence of disease. Although these particular farms are far from being ideal in other respects, they may be considered as approaching the ideal for the Gold Coast so far as the humidity factor is concerned. So we may take these two plots, 2 and 5, as a basis from which to judge the general significance of all factors. In these plots there is no appreciable additional incidence of disease which may be ascribed to injury.

TABLE 7.

P. Faberi. INJURY AND INFECTION.

Count F. 5,169 pods, 2,087 infections.

1. General.

Humidity group.	Plot.	Proportion of total pods infected.		Proportion of injured pods infected.		Proportion of uninjured pods infected.	
		Numbers.	Per-cent.	Numbers.	Per cent.	Numbers.	Per cent.
High.	1	475/752	63.1	96/123	78.0	379/629	60.3
	3	242/568	42.6	62/113	54.9	180/455	39.6
Medium.	2	510/1395	36.5	163/420	38.8	347/975	35.5
	5	471/978	48.2	121/329	38.0	350/649	53.0
Low.	4	187/632	29.6	71/415	17.5	116/217	53 4
	6	202/844	23.9	86/577	14.9	116/267	43.5
Totals ..	..	2087/5169	40.5	599/1977	30.2	1488/3192	45.8

TABLE 7—*continued.*

2. Detailed.

Humidity group.	Plot.	Numbers and percentage of infections in pods injured by—													
		Scale.		Helopeltis.		Sahlbergella.		Borer.		Thrips.		Unidentified Ins.		Mechanical injury.	
High.	1	0/0	0	8/11	73	1/1	100	20/24	83	3/6	50	17/31	55	47/50	94
	3	2/2	100	25/46	54	0/6	0	12/19	63	9/11	82	3/18	17	11/11	100
Medium.	2	1/1	100	22/87	25	0/5	0	17/38	45	0/1	0	81/240	34	42/48	88
	5	3/8	38	24/45	53	3/28	11	14/25	56	13/57	23	35/127	28	29/39	74
Low.	4	0/2	0	19/93	20	14/100	14	8/44	18	14/110	11	7/51	14	9/15	60
	6	0/2	0	14/122	11	1/11	9	3/17	18	32/272	12	21/128	16	15/25	60
Totals	..	6/15	40	112/404	28	19/151	13	74/167	44	71/457	16	104/595	28	153/188	82

TABLE 7—*continued.*

P. Faberi. INJURY AND INFECTION.

Count F. 5169 pods, 2,087 infections.

3. Infection after each type of injury.

Humidity group.	Plot.	Percentage of total infections due to:—					
		Scale.	Helopeltis.	Sahlbergella	Borer.	Thrips.	Mechanical injury.
High.	1	0	12	1	26	7	54
	3	2	48	6	20	12	12
Medium.	2	trace	48	3	21	trace	27
	5	4	22	14	12	28	19
Low.	4	1	26	28	12	30	4
	6	trace	27	2	4	61	6

4. Proportion of crop injured.

Humidity group.	Plot.	Percentage of pods produced injured by:—					
		Scale.	Helopeltis.	Sahlbergella	Borer.	Thrips.	Mechanical injury.
High.	1	0	1.5	trace	3.2	0.8	6.6
	3	0.4	8.1	1.1	3.3	1.9	1.9
Medium.	2	trace	6.2	0.4	2.7	trace	3.4
	5	0.8	4.6	2.9	2.6	5.8	4.0
Low.	4	0.3	14.7	15.8	7.0	17.4	8.1
	6	0.2	14.4	1.3	2.0	32.3	3.0

Centres of Spread of Infection.

A question of major importance is the method of carrying over of disease from one season to another, and the centres from which infection spreads when conditions become favourable, as the season advances, for wholesale infection.

The Significance of Husk-Heaps.

Much emphasis has been laid, in the past, both in this and other countries, on the existence of husk-heaps, which have been suspected of functioning as nurseries for disease fungi. A logical consideration of the facts elicited by observation, supported by experimental evidence, indicates that husk-heaps are of minor, if indeed of any, economic importance.

There are two aspects of the problem, *i.e.*, the significance of husk-heaps in the "over-wintering" of disease, and their significance as centres of infection during the bearing season.

Three points are worthy of attention before proceeding:—

(i) The key factor in incidence of pod disease is humidity, which can to a considerable extent be controlled by cultivation. There are so many facilities for spread of disease that no form of control is of much use in the absence of control of excessive humidity.

(ii) Insects are most probably the principal agents of transmission.

(iii) Rorer, who closely studied black pod disease (which is apparently the only significant pod disease in the Gold Coast) in the West Indies, states that the experience of farmers shows that treatment of husk-heaps is unremunerative.

A. Husk-heaps and "over-wintering".

1. After three or four months very few spores of *Phytophthora Faberi* can be found in husk-heaps, and most of these are empty and dead.

2. After three or four months husks are no longer attractive to insects which frequent pods and trees—they are rotted down and consolidated, and more or less converted into humus, and only the relatively small surface of the heap is exposed. The surface itself is washed by rain and partly covered with vegetable debris.

There are therefore very few chances of transmission of viable spores to pods on trees.

3. There is evidence to show that disease is carried over from one season to the next by diseased cushions—an extremely efficient method.

4. The first infections recorded this season showed no relation to the site of husk-heaps, which might be expected to occur if the latter are of any significance.

Husk-heaps are therefore probably of small importance as factors in over-wintering.

B. Husk-heaps durng the season.

1. For about a month after their formation husk-heaps are visibly covered with masses of spores of many fungi.

2. At this time they are very attractive to many kinds of insects which are also found on trees, on account of the fermenting mucilage.

These facts indicate that at this time there is some possiblility of infection being transmitted from husk-heaps to pods on trees.

3. *Phytophthora Faberi* cannot compete with saprophytes which over-run husks, and is therefore present in only a small percentage of the mass.

4. About 80 per cent of the husks examined, taken in large numbers from many heaps, were covered with *Trachysphaera fructigena,* which though a facultative parasite, has proved to be of no economic significance here. (See Section IV.)

5. Diseased pods on trees provide a source of infection immeasurably more efficient than husk-heaps. They are distributed throughout the farms and present a very great area of spore-bearing surface.

6. From 50 to at least 77 per cent of the total infections in plots from which data are available took place this season before active husk-heaps were formed.

7. The experimental evidence given below indicates that practically the significance of husk-heaps is very small and of no economical importance,

Husk-heaps therefore have little or no significance, even in their active state during the bearing season.

The Experimental Evidence.

Four plots were near to, or included husk-heaps, plots 1, 2, 3 and 5. The number of infections by *P. Faberi* and the total number of pods produced were recorded. The plots were marked out in zones (1) within 5 yds., (2) between 5 and 10 yds., (3) over 10 yds., from husk-heaps.

The percentage of the total pods which were infected in each zone was found, and is shown in tables below :—

I. Counting infections not due to contact with or drip from other diseased pods, these causes being not directly related to the proximity of husk-heaps.

	Within 5 yards.	5–10 yards.	Over 10 yards.	
Plot 1	24.3	32.9	35.5	Count E
Plot 2	39.2	28.5	21.6	4,001 pods
Plot 3	14.4	7.4	21.8	
Plot 5	36.4	28.9	27.4	

II. Counting all infections, whatever their direct cause.

	Within 5 yards.	5–10 yards.	Over 10 yards.
Plot 1	52.0	58.7	60.1
Plot 2	53.0	25.5	35.6
Plot 3	44.7	24.0	44.7
Plot 5	58.7	45.5	39.0

In the cases of plots 2 and 5 the figures indicate that husk-heaps exert a positive influence on the incidence of infection, but plot 1 shows a reverse gradation, while plot 3 shows no conclusive evidence at all. At the outset therefore, it must be admitted that the evidence does not support the theory that husk-heaps are of definite and considerable importance.

It is of interest to take the case in which the figures are most favourable to that theory—*i.e.*, plot 5, all infections,—and to see exactly what these figures indicate from the economic point of view in a farm of 3 acres producing 10 cwt of dry cocoa per acre.

The 5 yards zone round the heap has an area of approximately 170 sq. yds., or say, 0.01 of the whole farm. The 5-10 yds., zone has an area of approximately 270 sq. yds., or say, 0.02 of the whole farm. On the 5 yds. zone 9.7 per cent more infections occurred than in the over 10 yds. zone. In the 5-10 yds. zone 6.5 per cent more infections occurred than in the over 10 yds. zone. The 5 yds. zone produces about .01 of the whole crop, or about 0.3 cwt, while the 5-10 yds. zone produces 0.02 of the whole crop, or about 0.6 cwt. The total portion of the crop affected by the husk-heap is therefore 9.7 per cent of 0.3 cwt plus 6.5 per cent of 0.6

cwt,—in all about 0.07 cwt, or about 8 pounds of dry cocoa, value between two and three shillings. The actual effect on this small quantity is so small (see section on effect of disease on market product) that its value in money is negligible.

It may occur to the reader that there is a fallacy in this method of estimation—that in this farm not only the increased percentage in the zones near the husk-heap, but the whole incidence throughout the farm may have been raised by the heap. It is true that if husk-heaps have any influence at all their effect is not necessarily limited to these inner zones, although it might be expected to be greater there. But the comparatively even distribution of disease throughout farms indicates that this is not so, for the chances of distribution are inversely proportional to the square of the distance from the point of origin.

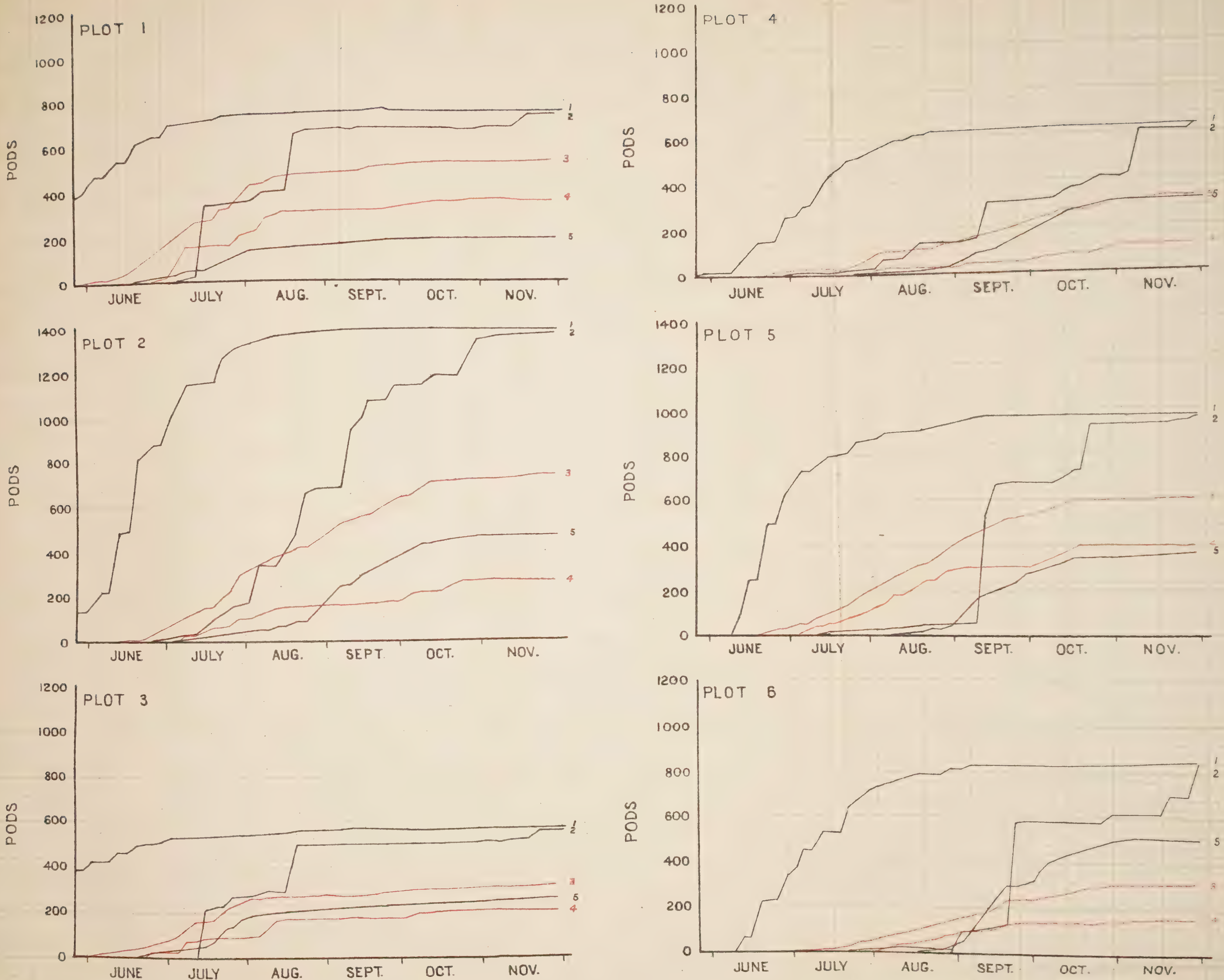
Perhaps the strongest evidence against the influence of husk-heaps in their active state is the fact that a very large proportion of the total infections in the season occurred before reaping, and therefore before the formation of active heaps! Thus, in plots 1, 3 and 5 respectively 50 per cent, 53 per cent and 77 per cent of the total infections occurred before the first reaping (see Plate V.) (In other plots small and frequent reapings prevent the extraction of useful data.) This shows that in the absence of husk-heaps in the active state there are other very efficient sources of infection.

It is indeed most probable that *P. Faberi* spores are conveyed in quantity to every pod in the farms, but that infection takes place only when favourable local conditions exist, as in the case of many parasites of animals and plants. It is indeed towards the control of environmental factors that we should look rather than to direct direct control of the parasite, for in the presence of favourable conditions for infection, control of the parasite presents such difficulties, both technical and economic, as to be definitely impracticable.

The only successful control treatment of husk-heaps which we have been able to find—successful in that it prevents dissemination of spores, whether that is of any significance or not—is burial, or alternatively covering with soil. In the case considered above, the crop, 30 cwts., produced by this farm means a husk-heap of about 15 cubic yards volume. So that in this, the best case we can make out for the theory that husk-heaps are an important factor in the spread of disease, the benefit gained from the labour of treating 15 cubic yards of husks amounts to a very small fraction of two or three shillings, the value of the total crop this season, in a depressed period, at 18 shillings a load, being about £50.

Such a method of control cannot be said to be economical, and the whole evidence indicates that husk-heaps are not worth attention.

PLATE V



1 – *Aggregate pods produced*

2 – *Aggregate pods reaped*

3 *Aggregate pods infected*

4 *Aggregate pods severely damaged by disease*

5 – *Aggregate pods ripened*

So many other factors affect incidence that impressions gained by casual observation are of little value. A casual observer, seeing a great number of infections in the neighbourhood of a husk-heap is inclined to connect the two facts as cause and effect. But similar bad patches may be seen remote from the heap, though these do not make the same impression on the mind.

Other Treatments for Husk-Heaps.

While the above data were being collected, several trials were made to find whether some cheap and simple treatment could be found which would destroy existing spores on husks and prevent further production of spores.

Husk-heaps were treated with solutions of various disinfectants in different concentrations. Izal and Metrogas fluid were found to be ineffective; after a few days the treated heaps exhibited the same amount of fungus growth as the controls.

Copper sulphate was used in 1 and 2 per cent solutions. In its simplest form, in which the solution was applied by means of a a tared perforated tin, the treatment was only partly effective. Husks lying with their inner surface uppermost retained some of the solution long enough, in spite of subsequent heavy rain, to prevent any further growth of either *P. Faberi* or *T. fructigena*, though harmless moulds appeared after some days, when the husks were blackened and no longer in a state permitting the growth of the former fungi. But husks lying with the convex side uppermost were subsequently attacked by *T. fructigena*.

Complete momentary immersion of husks in the 2 per cent solution completely prevented further fungus growth until the pods were blackened and only suitable for the growth of obligate saprophytes.

Such treatment, however, even if it were desirable to treat husk-heaps, is hardly practicable.

Thielaviopsis Paradoxa.

In cultures which were obtained from the feet of insects taken from husk-heaps, none of which produced *P. Faberi*, *Thielaviopsis paradoxa* was frequently found. Subsequently, the examination of newly-formed heaps disclosed the interesting fact that *T. paradoxa* was present in most of the husks, on the mucilaginous tissue, where it was producing micro and macro-conidia, and very luxuriant Stysanus bodies. (In previous cases of *T. paradoxa* parasitising the oil-palm, a *Sphæronema* was found associated with it. The same association was again found on cacao husks. In the former case the *Sphæronema* did not appear in pure culture from micro— and macro-conidia.)

T. Paradoxa is not known to infect cacao, but its presence in great quantity on husks is not without potential significance to other crops.

Diseased Cushions.

The question of the significance of diseased cushions has been referred to already in previous sections. It is not yet thoroughly understood, for the diseased condition of cushions is usually not apparent until the covering bark is removed, and such damage to the cushion prevents the bearing of fruit until the bark is renewed or a new cushion developed. It is therefore not easy to obtain statistical evidence, but it is hoped that work planned for the future will throw light on this problem.

The majority of the earliest infections recorded at Anyinam this season were definitely associated with cushions exhibiting the typical symptoms of canker. (The cushions were opened after their fruit had been reaped.) Other pods have been examined where the discolouration indicating infection was definitely extending along the cortex of the peduncle in an acropetal direction, and was continuous with discolouration in the cortex of the cushion. This was found by removing small pieces of the epidermis. Proximal infections followed. In other incipient proximal infections the same conditions were found in the peduncle and cushion. In pods which had contracted disease in other than proximal infections, and were left on the tree until completely involved, cultures of *P. Faberi* were obtained from the peduncular trace inside the cushions, which shows that the fungus can travel from the pod into the cushion, at least for some distance. That part of the life-history of *P. Faberi* which occurs in the cushion is not yet known.

In the section on " site of infection " it has been stated that diseased cushions probably account for part of the preponderating number of proximal infections, the study of which is complicated by the at present unknown value of the former factor. Judging by the large number of cases seen in which infection was proceeding down the peduncle, it seems probable that its value will prove to be appreciable.

Diseased cushions certainly provide the best opportunities for the initial seasonal activity of *P. Faberi.*

It has been often observed that material for the over-wintering of the fungus is also provided by the few odd pods which can usually be found on trees even at the end of the inactive season. But it must be admitted that, at least in some seasons, it is at this time exceedingly difficult to find a diseased pod, as for example, when one is required for laboratory purposes.

In dealing with this subject of diseased cushions, it may be added there is one particular case in which husks-heaps may cause trouble. Heaps are occasionally found piled up round the trunks

of cocoa trees, and a few cases have been seen in which these trees have borne no fruit on the trunks, and were cankered. The excessively moist conditions formed round the collar by a heap of juicy pods, and the presence of *P. Faberi* in the heap and perhaps in actual contact with the bark, may very easily result in bad bark disease in which the cushions become involved, and flower production thus prevented.

Similarly cankered and unproductive trees are commonly found remote from husk-heaps, and the occurrence of a cankered and sterile tree in the middle of a heap is not necessarily a proof that infection came from the heap. It is however so probable that the formation of heaps round the bases of cocoa trees should be avoided.

Review of all Factors.

Let us take the medium humidity group plots 2 and 5 as the basis and review the whole of the evidence in regard to factors influencing the incidence of disease due to *Phytophthora Faberi*. (It will be noted that the statistics for the medium group plots does not greatly differ from the general plot averages.) We find—

1. Humidity is the key factor. Apart from other factors, a farm in which humidity is properly adjusted shows in the 1926 season an incidence of about 40 per cent of the total trunk crop. (In the total crop figures this figure would be somewhat lower, conditions being rather less favourable to the incidence of disease in the case of branch pods.)

2. About 25 per cent. of the total infections, or the infection of about 10 per cent of the total crop, is due to contact with diseased pods.

3. About 11 per cent of the total infections, or the infection of about 4 per cent of the total crop, is associated with and probably due to drip from other diseased pods.

4. These two factors, contact and drip, together account for 36 per cent of the total infections, or the infection about 14 per cent of the total crop.

5. 25 per cent of the total infections are associated with injury. But we have seen that, in plots other than those in which humidity is excessive, injury is by itself of little or no importance. This 25 per cent must therefore be added to the class considered in (7) below.

6. All the other infections must be considered in the light of the evidence gained by the study of the site of infection.

7. 39 per cent of the total infections in the medium group plots were not associated with contact drip nor injury. The remarkably constant proportions of infections found in all plots and for all other factors, in the different regions of the pod indicate that we are here dealing with the factor of the host's morphology.

To this 39 per cent we must add the 25 per cent associated with injury but not appreciably affecting incidence of infection, making 64 per cent of the total infections.

An unknown proportion of this is due to infection from diseased cushions. The proportion—21 per cent—associated with lateral and distal infections is free from complication by the diseased cushion factor. This leaves 43 per cent to be divided between the effects of diseased cushions and morphological characters of the proximal region. The latter are responsible for a degree of influence which is obviously greater than that for the lateral and distal regions. Actually the question of the relative shares of the 43 per cent which are associated with these two factors is not of great practical importance, though it is of much interest, when we consider the means of control which are suggested.

We may tabulate the approximate results obtained :—

Factor.	Percentage of total infections.	Percentage infection of total crop.
1. Contact	25	10
2. Drip	11	4.5
3. Lateral and distal morphology ..	21	8 5
4. Proximal morphology .. .. 5. Diseased cushions	43	17
6. Injury	trace	trace
	100	40

The first four of these factors could undoubtedly be reduced to a considerable extent by controlling the growth of the trees, and almost completely eliminated if this control were supplemented by the introduction of a strain of Amelonado characterised by a slightly modified morphology.

The fifth factor, diseased cushions, would at the same time be correspondingly reduced in significance, for diseased cushions undoubtedly result from connection with diseased pods, except in those cases where they are infected by being involved in a bark canker.

We are left with the possibilities of infection due to the relatively small number of serious injuries which show a percentage of infections higher than the plot average borer and man-inflicted wounds, and with a residue due to all the other factors proportional to the efficiency of cultivation and of the desired new strain of Amelonado cacao.

The possibility of obtaining a strain immune to disease is too obvious to be overlooked. The work entailed in producing either a physiologically immune or a morphologically improved strain must inevitably be protracted in the case of a plant like cacao, which requires some years to reach maturity. It is however by no means an impossibility, and it is hoped that such work may be commenced very soon.

In the meantime however it is desirable to consider how much can be accomplished by other means. An investigation of the possibilities of controlling the form of young trees and of re-modelling old ones is worth while, and it is hoped that an early opportunity for the institution of this work may be found.

SECTION IV.

OTHER POD PARASITES.

Their Relative Significance.

The other parasites of the cacao pod in the Gold Coast have been described elsewhere (4), and it is not necessary here to refer in detail to their characteristics.

The total average incidence of pod disease recorded in this investigation was 55.4 per cent. of the total crop and different fungi were responsible for this in the proportions shown below :—

Phytophthora Faberi	40.5 per cent.
Colletotrichum sp.	6.2 ,, ,,
Botryodiplodia theobromæ ...	0.3 ,, ,,
Trachysphæra fructigena ...	0.1 ,, ,,
Unidentified	8.3 ,, ,,
	55.4 per cent.

Phytophthora Faberi is of course the major parasite, and has been dealt with in detail.

Anthracnose (*Colletotrichum sp.*) appears to account for a larger proportion of disease than has been previously supposed. The species of *Colletotrichum* which is the causative parasite is at present not definitely identified with any one of the relevant species which occur elsewhere, but preliminary cultural work indicates that it is probably *Colletotrichum Cradwickii,* Bancroft, for the characteristic setae of this species appear in the Gold Coast fungus, and are maintained in culture.

On the whole (Table 8) the incidence of anthracnose shows some association with injury, but this is by no means definite, owing probably to the comparatively small numbers of infections which were recorded. There is also a higher incidence in the drier plots, but this may be due to the evident fact, as pointed out by Nowell (5) that *Colletotrichum* is able to infect in less humid conditions than *P. Faberi.* In the more humid plots it is probable that a large proportion of incipient anthracnose infections are masked by the much more rapid progress of *P. Faberi* infections which occurred at about the same time.

TABLE 8.

Colletotrichum sp. INJURY AND INFECTION.

Humidity group.	Plot.	Proportion of total pods infected.		Proportion of injured pods infected.		Proportion of uninjured pods infected.	
		Numbers.	Per cent.	Numbers.	Per cent.	Numbers.	Per cent.
High.	1.	27/752	3.6	5/123	4.1	22/629	3.5
	3.	25/568	4.5	7/113	6.2	19/455	4.2
Medium.	2.	62/1395	4.5	21/420	5.0	41/975	9.2
	5.	63/978	6.4	19/329	5.8	44/649	6.8
Low.	4.	89/632	14.1	63/415	15.2	26/217	12.0
	6.	72/844	8.5	48/577	8.4	24/267	9.0
Totals ..	..	339/5169	6.6	163/1977	8.2	176/3192	5.5

After the pod tissues have been thoroughly exploited by *P. Faberi,* this fungus, through exhaustion of food material and self-intoxication, loses its vigour, and further growth ceases. At this time there is still much material capable of supporting secondary parasites and saprophytes, and the anthracnose fungus is invariably found on these pods.

The occurrence of the anthracnose fungus on very young pods must not be passed over. As in the case of cotton, the cacao tree sets far more fruit than its nutritional resources can bring to maturity, and a large proportion of the fruit set is cut off from the nutritional circulation at a very early age. These small pods do not fall at once, but remain attached to the tree until they are completely dried up. The first visible sign of this process is a change of colour from green to yellow, after which the pods are quickly involved in attack by *Colletotrichum.* The fungus however cannot establish itself until after the pods have been cut off by the parent tree. This process occurs generally when the pods are from three to six weeks old, but a few more may be rejected up to the age of about eleven weeks.

The occurrence of *Colletotrichum* on these pods is of no economic importance.

The strain of *Botryodiplodia theobromae* found in the Gold Coast is either less virulent than that described from other countries, or else the host in the Gold Coast is more resistant. The results

obtained in this investigation seem to confirm the writer's previous opinion that this fungus has no practical significance as a pod parasite. In this connection it is interesting to note that die-back due to this fungus has not been found in cacao in the Gold Coast. It has apparently not the slightest economic importance. Only 17 infections were found, and many of these were associated with the anthracnose fungus, to which *B. theobromæ* may have been secondary, and with necrosis probably due to other causes.

Trachysphaera fructigena, Bunt. and Tabor, causing "Mealy Pod" disease, was responsible for the infection of only 0.1 per cent of the crop observed, and this figure is evidently typical for the whole district, and probably for the whole country. It is nearly always possible to go into a set of farms and find a few infections by this fungus and by *B. theobromæ*, but it oftens necessitates a long search.

T. fructigena is evidently a weak parasite of cacao, though it is a very efficient parasite of Coffea liberica, and an efficient saprophyte on cocoa husks and other damaged fruits.

It is by no means safe to diagnose infections by their appearance —the apppearance of the *P. Faberi* spore mass sometimes is identical with that of typical *T.fructigena* spore masses, and vice versa.

The universal luxuriant growth of *T. fructigena* husk-heaps and the very small numbers of infections due to it in the same farms are significant.

There were also 430 undiagnosed infections. Some of these were on pods which were reaped after the recording of infection but before diagnosis could be made. Others were doubtful cases, obviously due to *Colletotrichum* or *B. theobromæ*, principally the former, which were reaped before they developed definite diagnostic characters. In the first case, the great majority were undoubtedly due to *P. Faberi;* in the second, to *Colletotrichum.*

SECTION V.

ARTIFICIAL CONTROLS.

The incidence of pod disease can be considerably reduced by cultural methods, and analysis of the factors concerned has shown that there is a wide field for experimental work here.

Side by side with this work however other possible means of control must be investigated.

Artificial methods of control involve the application of fungicidal chemicals to the host in the form of either a liquid spray or of a finely divided powder. The latter method, known as "dusting" has of recent years been greatly developed in other countries, has largely superseded spraying, and will undoubtedly do so in an ever-increasing degree in the future. In material and machinery dusting is as economical as spraying, while application is much easier and cheaper because water-haulage and mixing operations on the spot are obviated, and labour is thereby reduced to a minimum.

Trials were made with the object of ascertaining whether dusting is likely to be economically possible in the Gold Coast, by testing its effectiveness and cost.

Several dusts made by well-known British and American firms* were tested in the field and laboratory. Laboratory tests on dusted pods and slides clearly indicated that dust of the copper-sulphate-lime, and copper carbonate-lime, type are effective preventives of infection by *Phytophthora Faberi,* and that on pods infected previously to dusting the production of external spore masses is inhibited. These dusts are composed of copper carbonate, or dehydrated copper sulphate, and hydrated lime in varying proportions, for example, 12 :80. Part of the lime made may be replaced by an insect stomach poison, *e.g.,* calcium arsenate, which is useful in some cases, but probably not in the case of cacao, for preventing insect damage as well as infection.

In the field the dusts were applied after rain, or in the morning when pods were wet with dew. This is necessary in order that the dust may "set" successfully. In all cases however adhesion was poor, and within a few days rain washed off a large part of the dust. This defect alone of course renders the method impracticable.

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*California Sprayer Co., Los Angeles ; Niagara Sprayer Co., Middleport, N.Y.
W. H. BROWN & Co., London.

The same difficulty is experienced in Europe and America, though apparently in a much less degree, and attention is therefore being concentrated on the improvement of the adhesive qualities of dusts. American and European experts are convinced that such improvement can be made.

Factors other than that of adhesion indicate that there is every prospect of dusting becoming a practicable control in the future. In the case of cacao the object of treatment is to protect pods, and consequently it is necessary only to dust the pods, and not, as in the case of some other crops and diseases, to cover the whole of the foliage. Compared with other orchard crops, the number of fruits on an individual tree is small, and the fruit occupies a more or less definite position on the tree—*i.e.*, on the trunk and larger branches. In application the dust can be directed on to the pods, to the exclusion of the rest of the tree, and therefore only a comparatively small quantity of dust is required. In properly pruned trees of suitable shape, such as are not found in native farms, the treatment would be even more easy.

The nozzles at present fitted to dusting machines are not well adapted for use with cacao, and involve much waste of dust. Attention is being given to the devising of a more effective fitting. In the trials this year about 35 pounds of dust per acre per application were used, on trees 15 to 25 feet height planted about 500 to the acre. It is estimated that with a more efficient nozzle this could be reduced to about 20 pounds.

The number of applications necessary during the season will depend largely upon the efficiency of adhesion. The first application need not be made until the pods are half-grown, when they begin to become susceptible to infection. Reference to the section on the effect of meteorological conditions will show that we may expect periods of intense sustained humidity during the susceptible age of the pods in June—July and September—October. In the case of trees of normal periodicity and in normal seasons therefore it will probably be necessary to make the main applications towards the end of June and again at the end of August. In the case of early-bearing trees such as those in the riverside plots at Anyinam, at the beginning of June and again in August. In abnormal seasons times of application might have to be modified according to the weather—a study of meteorological records will indicate the critical periods.

Dusting machines at present cost £4 to £5 each, and will probably last for three or four seasons with the amount of use they are likely to have here. Improvements in these machines both as regards construction and cost are steadily being made. Among small-holders such as are the majority of Gold Coast farmers, a machine could be shared by two or three.

Ready-mixed dusts of the type referred to, obtained from America, cost rather less than £2 per 100 lbs, including freight. This cost can be reduced by about 50 per cent by purchasing the constituent chemicals in bulk and mixing them locally, the machines used for this purpose ranging from a simple home-made contrivance to power-driven machinery, according to the amounts which are to be dealt with.

It is, of course, not yet possible to estimate costs per acre per season. But a very rough idea may be obtained by assuming that four applications will be necessary, of 20 lbs of dust each, using an improved nozzle, at a cost of, with locally mixed dust, say £1. We may add £1 for depreciation of the machine and 3/- for two units of labour. This totals £2 5s. od. With imported dust £3 5s. od. But these figures are of course very unreliable.

Referring to the figures given for production per acre and the effect of disease on the market product, it is reasonable to suppose that at some future time, not perhaps very far distant, dusting may become an economic possibility. This will depend upon an improvement in the adhesive qualities of dusts and an improvement in market conditions such as has been mentioned. Other means of control, such as have been suggested in the section on the factors determining incidence may render artificial controls unnecessary. In the meantime, however, it is proposed to continue dusting trials from year to year.

SECTION VI.

EFFECT OF DISEASE ON THE MARKET PRODUCT.

Gold Coast Cocoa is of admittedly low quality. Apart from varietal characters and leaving out of consideration for the present the effect of market requirements, this poor quality is due to number of defects in the methods of preparation and marketing. These are—imperfect fermentation, imperfect drying (or subsequent wetting), the inclusion of unripe "beans", and beans damaged by disease.

The contents of pods attacked by disease are more or less involved in the infection, and the damage caused may affect not only the bean itself, but also preparation and storage.

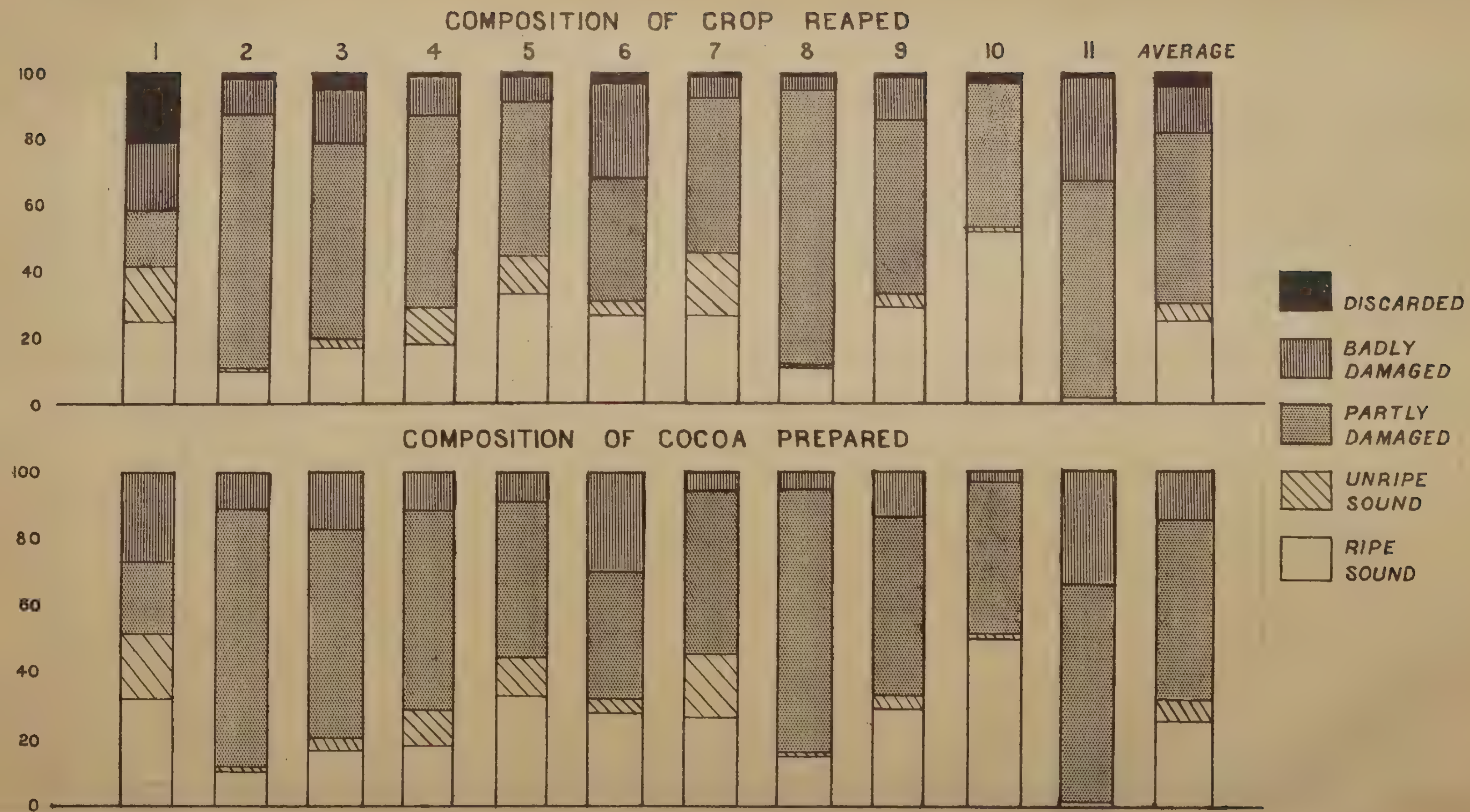
Infection usually takes place in the pod wall, which is thus first damaged, and subsequently spreads to the mucilaginous tissue surrounding the seeds, in the region nearest to the point of infection. This mucilaginous tissue provides an ideal nidus for fungi—hence the luxuriant fungous growth which takes place on husk-heaps.

In a later stage, when the general rot of the pod is pronounced, other fungi, principally saprophytes, but including *Botryodiplodia theobromæ*, and notably *Colletotrichum sp.*, invade the pod. In advanced cases the seeds themselves are killed, and dry (anthracnose) or wet rot ensues. For a long time before the cotyledons are visibly affected, the seeds are bathed in slime containing the products of decomposition of the pod and of the metabolism of the fungi.

The mucilaginous tissues provide the water and carbohydrates necessary for the growth of the yeasts which carry out the fermentation process, and the partial destruction of these tissues may affect the degree of fermentation of the mass if damaged beans are present in large proportions.

Actual damage to the seeds themselves may cause them to become deficient in those qualities for which they are valued, while their exposure to the action of fungus excretions and rotting mucilage may have a similar effect. This effect can only be ascertained by chemical analysis, and is not yet known. In advanced cases it is undoubtedly considerable.

PLATE VIII



Reproduced at Survey H.Q. Accra 1927.

Even when the cotyledons are not apparently damaged the effect on the testa is often considerable, and this circumstance may be of much importance in the question of the subsequent occurrence of moulds inside the seeds, a condition which greatly detracts from the quality and value of the product.

In this investigation a preliminary study of this problem was instituted by observation of local reapings and fermentations, and of specially arranged experimental fermentations.

The composition of a number of large reapings, each equivalent to about 3 cwts of dry cocoa, was analysed by scrutinizing the contents of each pod as it was broken. The condition of the contents cannot be judged by an examination of the unbroken pod. A pod completely involved in discolouration may have almost completely sound contents.

The classes into which the raw cocoa was divided were :—

"Sound"—Not attacked by disease. Beans pink, mucilage tissues white, very wet and slimy.

"Partly damaged"—Pods partly or wholly discoloured (brown). Mucilaginous tissue becoming brown, with tendency to dryness and adherence of beans.

"Badly damaged"—Pods blackened, shrivelled and more or less dry and hard. Mucilaginous tissue either brown and dry, with beans adhering in clumps, or black and slimy. In the latter case, beans often soft and easily crushed between the fingers.

"Discarded"—Pods completely hard and dry, shrivelled, contents rattle when shaken, beans dry, shrivelled and mouldy, connected by the stringy vascular elements of the completely disorganised mucilaginous tissue. These beans are discarded by farmers.

The results are shown in Plate VIII, for eleven reapings, with the average for the totalled classes.

It will be seen that while there was very little actual loss of crop, for only "discarded" pods are lost, a very large percentage of the product was associated with disease.

While we have as yet no evidence from chemical analysis, it is highly probable that the cotyledons are affected considerably in the "badly damaged" class, and the testa certainly is, while the mucilage tissue is no longer available for fermentation.

It is possible that the testa is affected to some extent in the "partly damaged" class, but the cotyledons are probably not affected. In this class fermentation may be partly affected by the fact that mucilaginous tissue is already partly exhausted by fungi.

In more or less full-grown and sound, but unripe, pods the mucilaginous tissue seems to be capable of supporting proper fermentation. In this case the full development of the valuable alkaloids, etc., may not have been reached—another case for future chemical research.

In the mixed heaps the mucilage present in the sound and partly damaged raw cocoa is apparently quite sufficient for the fermentation of the whole mass. In experimental fermentations, using (i) 100 per cent partly damaged cocoa, (ii) 50 per cent sound, 50 per cent badly damaged cocoa, fermentation took place satisfactorily, as shown by the dried cocoa. Few heaps are likely to contain a smaller percentage of available mucilage than in these tests, and it is not probable that pod disease has any appreciable effect on fermentation.

The possible economic significance of pod disease is therefore confined to its effect on cotyledons and testa. In the latter case there is some evidence that the subsequent appearance of mould is to some extent determined by disease. After six weeks the dried cocoa from experimental fermentations at Anyinam was examined. No mould was found in beans from a 100 per cent sound mass, but a good deal was found inside beans from 100 per cent partly damaged and from 50 per cent sound, 50 per cent badly damaged, heaps.

But the occurrence of mould in prepared cocoa depends on the presence of sufficient moisture, so that the effect of disease, and of other injury to the testa such as is caused by germination, is therefore a subsidiary factor.

Probably the only real significance of disease in its effect on the market product is in connection with chemical damage to the cotyledons, and we have yet to learn to what extent this affects quality. Whatever that effect may be, it is evidently confined, at least almost entirely, to the "badly damaged" portion of the crop. In the average analysis shown in Plate VIII this portion formed about 15 per cent of the whole of the cocoa prepared. The reapings examined were chosen, at different times during the season, as typical of the various groups of farms, and they give a very fair indication of the composition of the crop from the whole district.

These observations also show that only a very small loss is occasioned by disease. In the average analysis about 70 per cent of the crop reaped was diseased, but only about 4 per cent was lost by the farmer. (Total incidence of disease at the time of husking is often much larger than at reaping, owing to delay frequently occurring between these two operations.)

The actual economic significance of pod diseases is very well illustrated by this analysis of reapings and fermentations.

SECTION VII.

GENERAL CONSIDERATIONS.

Attitude of the Farmer.

The farmer, in his attitude towards those aspects of cultivation which affect the health of the host plant and the incidence of disease, is, it is feared, frequently unjustly criticised. In general his views correspond closely with those which were held by farmers in Europe not many generations ago, and which are by no means unknown at the present day. They are due not as is sometimes suggested to an inherent idleness, but partly to an imperfect appreciation of cause and effect which is quite natural when we consider the educational status of the vast majority. In part, too, the farmer's attitude is due to his very sound business instinct, and in these cases his attitude is sometimes perfectly proper and justified. For example, he has been blamed for the poor quality of Gold Coast cocoa, but he would be a poor business man if he improved its quality, at the expense of considerable extra labour, for he knows by experience that he does not get a better price for a better quality product. In short, he efficiently supplies a demand. In the past he learned to ferment his cocoa because the trade demanded fermented cocoa. If market conditions show definitely that the trade requires a further improvement the farmer will undoubtedly supply the demand.

Under present market conditions he can sell practically all cocoa which is affected by disease, and suffers only a small loss. He is therefore naturally averse to expending labour and money on control measures for which he can see no prospect of return. There is not the least doubt that his attitude in this particular case will change if the trade demands a better quality cocoa. A close study of the farmer's practice shows a very sound appreciation of all factors which affect the marketing of his product, and this is apparent in all operations from reaping to the sale. He has little to learn in this part of his work.

Farmers in all countries are traditionally conservative and difficult to convince of the advantages of improved methods. At the same time it is a fact that their fixed ideas and superstitions have frequently had some foundation in fact. Sometimes this has been overlooked, and we should not fail to give full attention to their opinions, however inaccurate they may appear on the surface.

In other respects the farmer's attitude is wrong through complete inability to understand the necessity for some cultural operations. With little education and no experience of agriculture beyond that gained in the cultivation of a few native food-crops, he cannot be expected to understand the physiological requirements of a recently introduced and foreign crop. Herein lies the great menace to the future of cocoa in the Gold Coast. The progress of education is inevitably too slow to play a part in the solution of this problem.

Other Factors Affecting the Quality of Cocoa.

In an earlier section the probable significance of disease as a factor in determining the quality of the market product has been dealt with. A brief survey of the other factors which influence quality may assist in making the whole question more clear.

The effect of the current market price must not be overlooked. It influences the farmer when he is deciding upon the time for reaping. The proportion of unripe, germinated and diseased cocoa found in the mass is largely dependent upon the state of the market.

Both the methods of preparation and handling affect quality. The native method of fermentation most widely practised consists of forming a conical heap of the raw cocoa, resting on plantain leaves on the ground in the farm, and covering this heap with several layers of plantain leaves. The heap is then left undisturbed for a period of four to seven days, after which the cocoa is considered to be fully fermented, and is removed to the village or farm hut for drying. The absence of any mixing process results in beans on the outside of the heap being frequently insufficiently fermented. Towards the end of fermentation moulds appear on the surface of the heap, and these may affect the cocoa subsequently. Moulds also establish themselves on the surface of cocoa which has been left in baskets for some time before being put out to dry.

Cocoa is dried either on mats of split bamboo or split raffia, raised on stringers and forked sticks, or on mats or tarpaulins on the ground. In some places wet or partly dry cocoa is bought by small traders, and this practice seems to be growing—it is popular because it provides the farmer with quick turn-over, which he is usually glad to get. Drying is sometimes slightly delayed by this trade, and moulds have a further chance to spread.

Generally, drying is performed satisfactorily in the end—buyers are reluctant to accept cocoa which is not thoroughly dry, or if they are anxious to buy, complete the drying themselves locally, before transferring the cocoa to the central stores.

During drying the cocoa is frequently wetted by rain, which protracts the process, and may have other bad effects. The writer has seen—and has unfortunately been afflicted by the odour of—

cocoa which has been thoroughly soaked and afterwards bagged up for the night, with the result that vinegary fermentation has set in. A thorough soaking in vinegar probably does not improve quality.

Some farmers ferment and dry badly diseased cocoa separately and sell it to small traders. Odd lots of good cocoa, too small for the regular buyers to deal with, are bought by the same people. These lots are usually less than a load (60 lbs.) Small lots of unfermented, mouldy and wet cocoa find the same destination. The whole mass is then judiciously mixed, and finally finds its way by devious routes and further mixings into the central stores.

In the hands of the large traders and exporters cocoa is carefully stored, and precautions are taken to keep it in good condition. But before it reaches these stores, in transit on lorries and in head-loads, it is subjected to much mishandling and wetting. It also absorbs moisture from the air at a rapid rate. Most of the external moulds collect before the cocoa reaches the exporters.

In beans which have germinated, or in which the testa is otherwise obviously damaged, moulds are invariably found. A very great proportion of the beans have undoubtedly suffered minor damage which is not apparent. The presence of external moulds on these inevitably results in internal moulding, which is a serious defect.

Some defects are not yet fully understood in detail, and require further investigation.

Casual Observations.

Opinions are frequently given by persons interested, professionally or commercially, in the cocoa industry which are the result of casual observation. In the case of cacao particularly it is by no means possible to obtain even approximately accurate information in this way, although it of course is in the case of many other crops.

For example, the protracted periods over which production and reaping take place render it impossible to estimate by a single visit the crop per acre. Similarly, estimates of the importance of disease are often highly inaccurate. A count at any one time of the proportion of diseased pods on the trees gives no indication of the severity of attack. The proportion of diseased pods fluctuates very greatly during the season, owing to the selective nature of reaping. Thus, in three plots at Anyinam in the 1926 season the percentage of diseased pods on the trees fell from 40 to 10, 50 to 5, and 50 to 0, after a fairly large reaping, although after the reaping about half the crop was still on the trees. In these plots the actual total infections were 60, 75, and 55 per cent respectively. In another plot. although the total infections involved over 50 percent of the crop, there was never more than 15 per cent

of disease in pods actually on the trees, and generally much less. A visit to any of these plots at any time during the bearing season would have given a completely false impression of the actual significance of disease.

A statement, for which the author was partly responsible, and which has been published (4), is to the effect that in a particular farm 80 per cent of the crop was destroyed by black pod disease. This figure was based on an actual count, and technically the statement is true—for the crop then on the trees. It was admittedly the worst case ever found, but as evidence for the potential economic significance of pod disease it is valueless, for one essential fact was omitted from consideration. The farm in question was situated in the riverside flats at Anyinam. When these flats are flooded, access to these farms is often impossible for a considerable period, during which, abnormally accelerated by the high and sustained humidity, pod disease does actually destroy most of the crop on the trees. Here we have a factor which can hardly be considered as having any bearing on the general problem—the farmers were in this exceptional case prevented from attending to their crop. Moreover some of the crop may have already been removed.

It has been seen, too, that loss, and the effect on quality of the product by disease cannot be even roughly estimated by examining unopened pods or the crop on the trees. In this investigation it was found at the beginning that an estimate of quality based on a classification of pods by their external appearance bore no relation at all to the actual quality revealed by husking.

It is evident that great caution must be exercised in interpreting information gained by casual observation.

SUMMARY.

1. The district in which this investigation took place is situated on an alluvial plain, sheltered by surrounding hills and forest. Local features are those of the river bed, and are of interest in the consideration of environment factors.

2. Well-defined types of farms occur, characterised by different conditions of water-relation due to their proximity to the river and relative degrees of overhead and lateral protection.

3. The district is very suitable climatically for cacao cultivation.

4. In the Gold Coast the physiological requirements of cacao usually make it necessary to adjust factors which determine the degree of humidity during the dry season, generally by the use of shade and lateral protection.

5. A study of the periodicity of production and ripening shows that in addition to farms of normal periodicity there is another type of farm which, favoured by conditions of water-relation, ripens the main crop about seven weeks before normal farms.

6. Cultural conditions and methods of planting in native farms are not generally good, and are very different from those in agricultural stations, which have previously been our only source of information.

7. But the yield of cocoa per acre in the native farms studied is much higher than has been generally supposed, and higher than in most agricultural stations while the number of pods producing one pound of dry cocoa is lower.

8. Of conditions which determine the severity of infection in the case of Black Pod disease, atmospheric humidity is the key factor.

9. Other important factors, some of which are more or less independent of a sustained high humidity, are due to morphological characters of the host.

10. In farms in which conditions of water-relation are well-balanced, injury to pods caused by insects and other agents is not a very important factor.

11. Accumulations of empty husks are apparently of negligible economic importance as centres of spread of infection.

12. A certain proportion of the incidence of Black Pod disease is caused by diseased cushions, which are also probably responsible in a large degree for carrying over infection from one season to another.

13. The proper cultivation of cacao necessarily results in the maintenance of a high degree of humidity, but by reducing this to the minimum the incidence of disease can be controlled to some extent.

14. Incidence can be further controlled by inducing an artificial habit in the host, thereby eliminating to some extent some morphological characters which favour infection.

15. Incidence could be further reduced by the production of strains of Amelonado cacao characterised by a modified morphology.

16. By combining all controls the incidence of disease could probably be reduced to very small, economically negligible proportions.

17. Of the parasitic fungi causing pod diseases only one is of considerable importance—*Phytophthora Faberi, Maub.*, causing Black Pod disease.

18. A larger proportion of the total disease than was previously supposed is due to *Colletotrichum* sp....(*Cradwickii*?), but it is still only a small proportion.

19. Other fungi found on diseased pods are of negligible importance.

20. Artificial control by dusting is at present neither an economical nor a practical possibility, but it may become so in the future if the adhesive qualities of dusts can be improved, if market conditions improve, and if other means of control are not instituted.

21. The native farmer has sound business methods in his preparation of cocoa and marketing, but his cultural methods are unsound through inability to appreciate the physiological requirements o cacao.

22. Factors other than disease, principally those of fermentation and storage, determine the quality of cacao.

23. Casual observation, as a method of estimating production, severity of incidence of disease, etc., is exceedingly unreliable.

H. A. DADE,
Mycologist.

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Department of Agriculture,

Gold Coast.

YEAR-BOOK

1926.

Issued by

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FOREWORD.

The first number of any series is generally found to be capable of improvement. This first Year Book of the Department of Agriculture does not pretend to be an exception to that rule, but it is offered as an excellent beginning, and every effort will be directed to detecting faults, avoiding them in future years, and to effecting improvements.

I desire to call attention to the satisfactory manner in which the members of the staff have responded to the invitation to contribute articles for the Year Book, and I wish to express my high appreciation of the courtesy of the Honourable the Surveyor-General in permitting his staff to prepare many of the illustrations; I have to thank those members of his staff for the thorough manner in which they carried out our requests.

Finally, I desire to call attention to the readiness with which Mr. G. G. Auchinleck, Deputy Director of Agriculture, undertook the onerous duties of editor and to the care he has devoted to performing them.

C. H. KNOWLES,

Director of Agriculture.

ACCRA, 14*th February*, 1927.

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ILLUSTRATIONS.

PAPER No. I.

THE DEPARTMENT OF AGRICULTURE AND THE AGRICULTURAL INDUSTRIES, 1926.

By C. H. Knowles, B.Sc. (Lond.).
Director of Agriculture.

Cocoa Prices.

A record has again been established for the export of cocoa which reached 225,920 tons for the calendar year 1926. The whole of the main crop season has been characterised by high prices, which reached a point never attained since the boom years of 1919 and 1920.

Sanitation.

The work under the Plant Sanitation Scheme was found to be quite satisfactory so far as eradication of pests was concerned, but very slow and therefore costly. It was considered necessary to change the methods of procedure. Under the new system the duties of the Inspectors are to give to farmers near each town demonstrations of the methods to be applied to the farms where the declared pests exist. This enables each Inspector to cover a comparatively large area and the whole of the cocoa areas will be covered in a reasonable time. The farmers have then to apply the methods shown at the demonstration. After a lapse of six months the Inspector can visit the farms in the areas in which demonstrations have been given and institute proceedings against farmers who have failed to apply the necessary measures, while at the end of twelve months the Inspector can do the necessary work with employed labour at the expense of the farmer. Work has progressed on the whole very smoothly and the demonstrations have been well attended.

An interesting investigation was carried out by Mr. H. A. Dade, on the incidence of disease in pods. It was necessary to follow the main crop right through from small pods and information as to the complete history of a crop has thus been obtained. An outline of the investigation is included in the Year Book.

The export of cocoa forms a steady drain on the mineral resources of the soil, for nothing is added to the soil by the farmer to replace the loss. The use of artificial manure is unknown, and the effects of the use of suitable manures have so far not been certain. With the view of commencing to obtain information on this important point, manurial experiments were laid down during the year on several of the Stations of the Department.

Oil Palms.

Mr. G. G. Auchinleck, Deputy Director of Agriculture, during the year has visited Java, Sumatra and the Malay States to investigate the oil-palm industry. A valuable and interesting report has been submitted and is being published separately, while some notes are included in the Year Book.

It is quite clear that, if this country is to compete with the countries where the oil-palm industry is an organised plantation industry under the supervision of highly trained officers and with the most modern machinery into which every improvement is introduced as soon as possible, we shall have to follow the same procedure. The local industry, which comprises the preparation, by crude methods, of small quantities in a large number of centres in oil-palm belts, will probably always continue to supply local demands, but even there some improvement is possible. Sets of hand-power machinery have been obtained and are used for demonstration purposes at suitable centres. The machinery consists of a kettle for steaming the fruits, a machine for removing the pericarp from the nuts, a screw-press for pressing the oil from the pulp, and a machine to crack the shells of the nuts. The oil produced by the use of this machinery is of a much superior quality to that produced by the usual crude methods.

The plantation system would have to be established on a large scale. In the East, 12,000 acres is regarded as the minimum area for a modern mill. This means the use of a correspondingly large amount of capital. There are certain difficulties here, but it is considered that these difficulties are not insuperable.

Cotton.

The encouragement of cotton cultivation in the Northern Territories was decided upon during the year and since funds were provided in the middle of the year the scheme has been actively pursued.

Cotton has always been cultivated by the people in the Northern Territories for their own purposes, and was found as a pure cultivation in many cases by the writer during a visit at the end of 1925. There are therefore none of the difficulties attendant upon the introduction of a new crop. The steps taken were to introduce from Nigeria cotton seed of a good strain likely to suit the country, to guarantee a price for the clean, mature seed-cotton the produce of that seed, to build a ginnery and to establish a farm where trials with and selection of cotton may be carried out. The people have readily taken up the seed offered to them. There are practically no exports of any kind at present from the Northern Territories and cotton-growing seems perfectly suitable for the purpose of establishing one. Stores will almost certainly follow where the people can satisfy their desires for an improved standard of living which will surely develop.

The ginnery is now in course of erection and it remains to be seen what the results are. The present season (1926-27) unfortunately has not been a good one, and the crop will be much less than anticipated but the establishment of an industry does not depend on the results of one season, so it will be some time before any definite statement can be made, but the future of the industry is contemplated with considerable confidence.

Coconuts.

The Department's plots along the coast have steadily progressed. The 300 acres at Atuabo in the Western Province are now rapidly coming into bearing. Arrangements have been made for the construction of drying apparatus, store rooms, &c.

At each plantation it is proposed to erect dryers both for drying by exposure to the sun and by artificial heat. The former will consist of trays running on rails, arranged so that they may rapidly be run under cover one under the other at night time or in case of rain, while the artificial dryer will be constructed of concrete and will consist of a chamber, containing trays on which the material to be dried is placed. A current of warm air passes through the chamber by natural draught. Either of these dryers can be constructed from materials readily obtainable in the country. Details of construction and results obtained will be published in due course.

Sisal Hemp.

The Accra Sisal Plantation has had a successful year. The working costs have gradually been brought down, while the quality has been improved by the installation of more efficient brushing machinery and a baling-box to take fibre full length. The output of fibre in the calendar year 1926 has exceeded the estimate of 400 tons. But the growth of the young plants used to replant the older areas and the replanting itself was interfered with owing to want of rain. An offer to buy the plantation and mill, to take over from the Government its interest in the sisal industry, to extend considerably the area planted and to continue to encourage the people in the vicinity to plant sisal, made early in 1926, is not yet settled.

Limes.

The encouragement of lime planting near Abakrampa in the Central Province has been quite successful. The area planted has been more than was originally asked for and the plants are receiving careful attention and have grown well.

A site for a lime-juice factory has been selected and the matter now must wait until the plants are reaching the bearing stage, when Messrs. Rose and Company, Ltd., have promised to erect a factory.

Rice.

It has been decided that any encouragement given to rice-growing should be only for swamp-rice, not the upland varieties. As swamp-rice growing is not an industry here, Mr. C. Saunders, Provincial Superintendent of Agriculture in the Western Province, was instructed to break his journey at Sierra Leone on returning from leave, for the purpose of investigating swamp-rice growing which is an industry of very considerable magnitude. Since returning Mr. Saunders has visited parts of the Western Province and found areas of land which seem suitable for the purpose. Seed is being secured from Sierra Leone and the growing of swamp-rice will be tested during the coming season.

The rice-mill has at last been completely equipped and adjusted and is now ready for use. During the last year or so the people have not been growing as much rice as they usually do, but now that the mill is ready to turn out rice in any desired state of preparation and in considerable quantity, it is believed that the people will take proper advantage of it.

Fruit.

Samples of bananas, grape fruit, oranges, limes and coconuts, &c., were sent to the Director, Gold Coast Commercial Intelligence Bureau, London, who used them for exhibit at the Imperial Fruit Exhibition 1926.

As this was the first time fruit from the Gold Coast had been exhibited at an Exhibition of this sort, it attracted considerable attention. Considering that proper facilities for sorting, grading and packing the fruit did not exist here, and the lack of previous experience, the fruit turned out in very satisfactory condition. Further trial shipments especially of grape fruit are arranged for. The grape-fruit is reported to have a fine and distinct flavour and appears to offer most possibilities. A careful examination of local fruit trees is being made for the purpose of selection and propagation of the best fruit.

Rubber.

The export of rubber reached a very satisfactory total, and there is no doubt that the Para rubber industry can be very successfully followed in West Africa. The increase is of course due to the increased prices of the last two years and, given stability of these prices, the interest in the industry will not only be maintained but is likely to increase.

An interesting feature is the manufacture of Funtumia latex into sheet rubber and the discouragement of its manufacture into balls or any other form. When prepared with care, Funtumia sheet appears to be quite a satisfactory product.

Organisation.

The Department of Agriculture work in connection with the above products, and the general routine of the Department have followed the same lines as in previous years. Certain defects in the organisation of the Department which have been noticeable for some time have at last been made the basis for a reorganisation of the Department. Proposals are now being drafted to enable investigations into agricultural problems to be more expeditiously carried out, to ensure accuracy and to put the special training of the highly qualified officers to better use.

PAPER No. II.

THE OIL-PALM PLANTATION INDUSTRY IN SUMATRA AND MALAYA.

By G. G. AUCHINLECK, M.Sc., F.I.C.,
Deputy Director of Agriculture.

The Eastern plantations of oil-palms are being described fully in Bulletin 8 of the Department of Agriculture. The present paper gives a brief summary of the position in 1926.

Areas.

The areas planted in oil-palms have increased regularly during the past few years.

Year.	*Area under cultivation.* *Sumatra.*	*Malaya.*
1915	6,500 acres.	10 acres.
1920	22,400 ,,	1,125 ,,
1921	24,250 ,,	2,067 ,,
1922	30,600 ,,	2,460 ,,
1923	38,000 ,,	4,320 ,,
1924	46,800 ,,	6,544 ,,
1925	60,350 ,,	9,694 ,,

In 1926 the normal annual increase in acreage of about 25 per cent may be expected on established estates, and in addition three companies have taken up new land-concessions for 120,000, 100,000, and 50,000 acres respectively with a view to future plantings if the industry proves to be a commercial success.

Types Grown.

The average composition of the Deli type is as follows:—

	% Bunch.	*% Fruit.*
Kernel-oil	1.9	4.2
Kernel-fibre	1.8	4.1
Shell	14.1	32.2
Pericarp-oil	13.2	30.0
Pericarp-fibre, moisture, etc.	13.0	29.5
Whole fruit	44.0	100.0
Stalks, bracts, etc.	56.0	
Whole bunch	100.0	

The Deli type originally came from West Africa. It is being gradually improved in composition by careful, skilled selection in Sumatra. The selection is aimed at increase in yield of oil per tree and per acre, and at an increase in thickness of pericarp with corresponding lessening of the thickness of shell. The removal of palms of low yield from the plantations and their replacement by selected types is a matter of ordinary estate routine.

Field Methods.

Germination of seed is speeded up by different devices, and it is claimed that 80 per cent germination can be attained in 2 to 3 months instead of the normal 60 per cent in 12 to 14 months. The best method in Sumatra is to soak the seed for 7 or 8 days in water, the water being warmed three times daily to a temperature of 45° to 50° C (113° to 122° F). Recently, equally good results have beeen claimed in Malaya by germinating in sand-beds covered with a glass frame.

The young plants are set out in the fields in triangular fashion at a distance of 9 metres (29.2 feet) apart. Clean-weeding has been shown to have disastrous results, and the land is therefore covered with leguminous green-dressings or left unweeded, the weeds being periodically cutlassed back.

The earlier practice of cutting away all leaves up to the bunches of fruit is now condemned. Dead or damaged leaves are removed, but the leaves immediately below the fruits are not removed until after the bunches have been reaped.

Artificial pollination has been proved to give greatly increased yields, but the resultant heavy crops are too great a burden on young palms. This procedure has therefore been discontinued on most estates, although it will probably be revived in moderation when systematic manuring begins to augment the strength of the palms.

Yields.

The palms begin to bear at $2\frac{1}{2}$ to 3 years of age. The mean yields of several estates in Sumatra and Malaya are given as follows :—

Age of Palms.	*Pounds of pericarp-oil per acre.*	
5 years ..	260	mean of 5 Sumatra Estates
6 ,, ..	441	,, ,, 10 ,, ,,
7 ,, ..	682	,, ,, 10 ,, ,,
8 ,, ..	962	,, ,, 9 ,, ,,
	1,343	one Malaya Estate
9 ,, ..	1,130	mean of 7 Sumatra Estates
10 ,, ..	1,083	,, ,, 7 ,, ,,
11 ,, ..	927	,, ,, 6 ,, ,,

The decline in yield after 9 or 10 years is stated to be due to the facts that many early mistakes in cultivation have been committed, and that systematic manuring has been started only within the past year.

Several cases of high yields have been recorded from estates. In 1925 an estate in Sumatra of 410 acres of 11-year old palms averaged 1919 pounds of pericarp-oil per acre. Other cases of high yields were obtained from an estate in Malaya.

		Pounds pericarp-oil per acre.		
Field No.	*Acreage.*	*Sixth year*	*Seventh year.*	*Eighth year.*
4	60	2,555	2,284	2,100
1	20	—	1,622	2,130
10	80	—	1,721	2,190

It is probable that an average yield of three-quarters of a ton of oil per acre will eventually be attained in Sumatra and Malaya, as methods of cultivation and manuring improve.

These figures may be compared with the following figures obtained from groves in the Gold Coast in 1924/25.

Locality.	*Acreage.*	*Yield of pericarp-oil: pounds per acre.*
Eastern Province	.. 15 acres	340
Central Province	.. 15 ,,	192
Western Province	.. 70 ,,	156

These figures are based on the assumption that 20% of the weight of fruit is obtained as pericarp-oil.

Factory Methods.

Several fine, modern factories have been erected in Sumatra in the past three years by Messrs. Krupp & Co., of Germany. The capacity of these factories is usually 10,000 tons of pericarp-oil output per annum each. The cost appears to be in the neighbourhood of £10 capital per one ton of oil output, so that a factory turning out 10,000 tons of oil per year would cost £100,000 to erect.

In general, the factory processes include
(a) steam-sterilization of whole bunches,
(b) double-pressing of fruits in hydraulic presses
(c) benzene-extraction of residual oil in fibre.

In the most recent factories, the railway trucks with their loads of bunches are run into the steam-steriliser, six at a time, and steam forced in. The oil from these factories can be produced with a maximum acidity of 1 to 3 per cent., (free fatty acid) owing to the rapid and efficient sterilization.

In no case in Sumatra has the centrifugal method of separating the oil from the fruit been retained. It is claimed that centrifugalling yields 24 per cent of the weight of fruit in oil, against 29 to 30 per cent obtained by the hydraulic press and benzene extraction.

Broken shells are separated from kernels by means of an elutriator which works in clean water, and the old, inefficient and dirty clay-bath method will eventually disappear.

Transport of Oil.

The cost of casks for packing the oil is very high. One estate in Malaya reports that total charges work out as follows :—

Plantation and factory costs £6 per ton of oil.
Casks for packing £6 per ton of oil.
Transport to coast and to Europe £6 per ton of oil.

To reduce this charge for packages, the oil in Sumatra is being railed to the coast in 7-ton cylindrical waggons, and there discharged into large tanks to await shipment.

Plans are being worked out for shipment of the oil in bulk by tank-steamers, but up to 1926 these arrangements had not been perfected. There is no serious technical difficulty to be anticipated, however, and it is probably only a matter of a year or two before all oil will be exported in bulk.

PAPER No III.

THE EFFECTS OF CULTIVATION ON WILD OIL-PALMS IN THE WESTERN PROVINCE.

By C. SAUNDERS, N.D.A., N.D.D.,
Provincial Superintendent.

In late years attention has been drawn to the declining interest taken in the oil-palm and the palm oil industry of this Colony, and various suggestions have been made as to means by which the industry could be restored to its former importance.

These suggestions, generally, have been prompted from the manufacturing standpoint, with the view of making the best use of the fruit obtained by present methods, and turning out a superior commercial oil by means of mechanical extraction.

There is little doubt that this is essential to enable the industry to compete in the world's markets, where a higher grade oil is demanded than that usually prepared by the hand process. This side of the industry requires modernising, and to be brought up to date.

The stock-in-trade required for mechanical extraction is, of course, costly to purchase and costly to maintain, and if such an undertaking is to be worked economically, large and almost constant supplies of palm-fruits must be forthcoming.

By the old methods of extraction the work could be carried on in a casual and intermittent manner, but such is not suitable for the modern specialised means of extraction.

Conditions in Western Province.

In the Western Province we are favoured by having a modern factory situated within the palm belt, but with that aid all is not plain sailing; difficulties are being experienced in keeping up constant and sufficient supplies of fruit.

The Province is rich in natural growth of the oil-palm. From the eastern boundary to the Nyan River there is a zone, several miles in depth, where the oil-palm predominates over other forest growth. This is gradually extending. As the heavy timber forest retreats inland its place is taken by palm growth. Farther to the west, wherever conditions are suitable, and in many inland areas

where the forest has been cleared of heavy timber for firewood, the oil-palm is found to be taking a prominent place. It is also found throughout the forest areas of the Colony and Ashanti. What has been said about the Western Province can be applied with little modification to each of the other Provinces of the Colony.

With this wealth of natural growth, the Gold Coast should occupy a very strong position in the oil trade, and be able to maintain it against any competition; yet the industry has dwindled from one of importance.

The cause is not difficult to understand, and in the main is due to :—

(a) The competition of other forms of employment.

(b) Difficulties connected with collection of palm fruits.

(c) The laborious and wasteful methods of making oil by the hand process.

The object of this paper is to throw some light on the difficulties there are in collecting the large quantities of fruit under existing conditions, and to suggest some means by which increased returns may be obtained for the labour involved.

Factors Affecting Yields.

At present, the work of gathering fruit is difficult, and there is much waste in time and labour wandering through the palm bush in search of fruit. Much of this could be avoided if some—even rough method of cultivation were adopted.

The palm in its natural state is found growing in a tangled growth of low bush with which it is in constant competition for all that is essential for growth.

Any plant growing under such conditions could be expected to be a poor producer of fruit.

To the casual observer it is evident what a small percentage of palms are found to be fruiting, and to what extent the collector must search the bush to obtain any quantity of fruit, and having found it, what work there is in connection with gathering it.

Palms vary considerably in their fruiting capacity. Some appear to produce nothing but male inflorescences, others exclusively female inflorescences and eventually fruit.

Others again appear to bear fruit during one season and male inflorescences the next. Of the fruiting palms some will be found to be producing only one bunch in the season whereas another may be seen carrying 8 bunches at a time, and probably giving a second crop in the season.

Every variation is to be found; as to what extent these variations are due to some physiological character of the individual palm, and to what extent due to external influences brought about by local conditions it is difficult to say, at present, but undoubtedly, light,

air and moisture play a very prominent part. When this is understood, it will be realised that though a palm area may be well stocked with palms yet the return in fruit from it may be very small, or vary considerably from season to season.

Yields of Trial-Plots.

At the Government Oil Palm Plantation, Anaji, two plots of 20 acres each of natural palm bush have been under observation and the yields recorded, since July, 1924, and the small return of fruit obtained from them is surprising.

These returns have been worked out to yield per acre, and are set forth in the table opposite, where a comparison is also made with another plot of 50 acres of similar palm land which has been cleared of all growth except palm and receives a rough kind of cultivation (semi-cultivation).

These yields are in pounds of bunches per acre.

In 1924 a census was made of the palms.

Plot " B " had an average of 53 palms of fruiting age per acre and 51 over 2 years and not then of fruiting age per acre.

Plot " D " an average of 49 palms of fruiting age per acre. and 52 over 2 years and not then of fruiting age per acre.

Many of these young palms should now be of fruiting age.

As these observations have been carried on for 2½ years, they can be taken as giving fairly reliable information as to the amount of fruit to expect from an area of natural palm growth, and the advantages of cultivation.

The average yield per month during the 30 months they have been under observation, is as follows :—

Plot " A ". 121.9 lbs average per acre, per month.
Plot " B ". 43.3 lbs average per acre, per month.
Plot " D ". 35.1 lbs average per acre, per month.

This shows fairly clearly to what extent the oil palm will respond, even to a rough form of cultivation.

In comparing the yields of the above table it will be noticed that there was very little difference between the yields of plot " A " and " B " during the first 12 months, but immediately the palms could show the benefit of the changed conditions in terms of fruit, the yields of plot " A " forged ahead, until now the average yield per acre is near the ratio of 7½ to 1 for the last 12 months.

COMPARISON OF YIELD PER ACRE BETWEEN PLOT "A" (UNDER SEMI-CULTIVATION) AND PLOTS B & D. (IN THE NATURAL STATE).

WEIGHT OF BUNCHES PER ACRE.

1924.	"A"	"B"	"D"	*Rainfall.*
July	—	—	—	4.18 inches
August	21.8 lbs. per acre.	17.7 lbs. per acre.	—	0.30
September	31.2 ,, ,,	8.8 ,, ,,	18.9 lbs. per acre.	1.12 ,,
October	59.4 ,, ,,	35.3 ,, ,,	8.8 ,, ,,	8.66 ,,
November	84.6 ,, ,,	15.9 ,, ,,	12.7 ,, ,,	3.04 ,,
December	177.4 ,, ,,	74.1 ,, ,,	73.9 ,, ,,	4.65 ,,
	374.4	151.8	114.3	
1925.				
January	215.6 ,, ,,	147.0 ,, ,,	109.2 ,, ,,	—
February	194.3 ,, ,,	190.0 ,, ,,	101.9 ,, ,,	1.32 ,,
March	177.5 ,, ,,	106.4 ,, ,,	252.0 ,, ,,	3.40 ,,
April	72.8 ,, ,,	67.2 ,, ,,	108.4 ,, ,,	2.79 ,,
May	189.8 ,, ,,	204.3 ,, ,,	177.1 ,, ,,	3.43 ,,
June	Nil	Nil	11.2 ,, ,,	25.08 ,,
July	52.0 ,, ,,	28.0 ,, ,,	Nil	12.26 ,,
August	76.7 ,, ,,	21.0 ,, ,,	Nil	1.22 ,,
September	106.9 ,, ,,	16.8 ,, ,,	5.5 ,, ,,	2.19 ,,
October	71.7 ,, ,,	51.8 ,, ,,	1.1 ,, ,,	2.09 ,,
November	126.5 ,, ,,	16.8 ,, ,,	Nil	0.31 ,,
December	114.8 ,, ,,	51.8 ,, ,,	8.9 ,, ,,	1.50 ,,
	1,398.6	901.1	775.3	
1926				
January	222.3 ,, ,,	51.8 ,, ,,	27.4 ,, ,,	0.66 ,,
February	257.0 ,, ,,	39.7 ,, ,,	47.0 ,, ,,	0.50 ,,
March	311.7 ,, ,,	80.1 ,, ,,	48.1 ,, ,,	1.50 ,,
April	251.7 ,, ,,	16.2 ,, ,,	20.1 ,, ,,	1.42 ,,
May	180.5 ,, ,,	6.1 ,, ,,	8.9 ,, ,,	11.20 ,,
June	148.0 ,, ,,	7.2 ,, ,,	2.2 ,, ,,	13.81 ,,
July	9.9 ,, ,,	2.8 ,, ,,	Nil	0.89 ,,
August	49.8 ,, ,,	Nil	Nil	0.17 ,,
September	98.0 ,, ,,	5.5 ,, ,,	Nil	3.99 ,,
October	86.2 ,, ,,	9.8 ,, ,,	Nil	3.93 ,,
November	103.6 ,, ,,	8.4 ,, ,,	2.8 ,, ,,	1.52 ,,
December	165.7 ,, ,,	19.6 ,, ,,	7.0 ,, ,,	
	1,884.4	247.2	163.5	

[If we assume that the weight of the fruit is 50 per cent. that of the bunches, and that 25 per cent. of the weight of fruit is recoverable as pericarp-oil, the yields for the years 1925 and 1926 of these plots are as follows :—

Pounds of pericarp-oil per acre.

	1925.	1926.
Plot A	175	235
,, B	113	31
,, D	97	20

On the plantations in Sumatra, the usual yield of pericarp-oil per acre recovered and shipped, ranges from half a ton to one ton.—EDITOR.]

Conclusions.

If the palm bush in the near vicinity of the villages were to receive only such attention as would relieve the palms of shade and entangling bush growth the yields could be reasonably expected to be trebled, with a corresponding decrease in labour connected with collection. The oftener a palm is worked, the easier the collection becomes.

Unfortunately under the communal system it is no one's business to try and improve the palm bush where any is free to gather, but the lesson is there for any one willing to benefit by it.

The best fruiting palms are generally to be found on old farming areas, where in course of the cultivation of other crops, the palms have been thinned out and freed from competition with bush growth, benefiting by the cultivation given to the area in connection with the growth of other crops.

Unfortunately in clearing for new farms the thinning is carried too far, and many valuable palms are needlessly destroyed.

Much can be done to improve these farm areas, where a type of individual ownership is recognised.

When new farm lands are being prepared, a selection should be made of the palms, and those retained which are good fruiters, and spaced at intervals of 30 feet. Palms with stems 7 to 8 feet high are more suitable, and more useful than the tall palms usually left standing.

If the palms are trimmed up, the under-grown crop will suffer little harm from shade. Any open spaces there may be, should be planted with palm nuts at the time the first crop is put in.

These nuts should be obtained from a good fruiting palm, and about 10 nuts placed in each hole,—the plants resulting to be thinned out later. By the time the farm is abandoned, and allowed to revert to bush, these young palms will have got ahead of other growth and will be able to maintain their lead.

By this means the abandoned farm lands will be turned into valuable palm areas, yielding far larger returns than could be obtained from an equal area of virgin bush, and from which fruit could be collected with far less labour.

Another interesting point that is brought out by the Table given is how the highest yields of fruit occur at periods of low rainfall, or in other words the apparent effect a high rainfall has on the palms at the time the fruit is setting, as shown in the larger yields obtained 6 months or so later.

PAPER No. IV.

EXTRACTS FROM THE REPORT ON OIL-PALM WORK AT ODUMASE

OF F. N. HOWES, M.S.C., F.L.S.,
Formerly Botanist to Department.

Thin-Shelled Palms.

On arrival at Odumase in June, 1926, steps were taken to isolate and mark thin-shelled palms. In all, some 30 such palms have now been found, these forming a basis for pollination work : of these, five are in Plot B, and the remainder in Plot A. Thin-shelled palms were isolated by taking samples of, and examining fruit from bunches as they ripened on the palms.

Thin-shelled fruit is very different in structure to thick-shelled. On the whole, thin-shelled fruit is smaller and more elongated than the thick-shelled, though no marked difference appears to exist in the size of the bunches ; bunches of thin-shelled fruit quite as large as any of the thick-shelled having been noticed. A very marked feature about thin-shelled fruit is the small size of the nuts, which are spherical, and not uneven in shape or pointed, as often are the thick-shelled forms. Another feature is the depth of pericarp and fibre that exists in the fruit at the bases of the nut : a strong contrast to thick-shelled forms where, apart from the apical end, pericarp and fibre are more or less evenly distributed round the nut. This feature renders possible as a rough and ready means of spotting thin-shelled nuts, biting or cutting with a knife the basal end : if the " nut " appears close to the surface the fruit is thick-shelled, if well away from the surface, thin-shelled.

Samples of fruit from each thin-shelled palm have been preserved for reference and for comparison later with their offspring, should they be used as parents.

In addition to the 30 thin-shelled palms already marked, there are undoubtedly many others present in the plantation which it is proposed to isolate in a subsequent visit. Undoubtedly it would be desirable to have recorded the fruit yielded by these thin-shelled palms, and so pick out in time the heavy yielders from the medium and low yielders. Such figures, compared with those already being recorded on the plantation, would also give indication as to whether thin-shelled palms yield normally more or less fruit than thick-shelled : a large number of palms, 30 or more, being necessary for figures of this sort to be of value.

The following two sets of figures prepared by the Agric. Chemist from fruit forwarded from Odumase illustrate the main differences in composition of thick and thin-shelled fruit :—

	Thin-Shelled.		*Thick-Shelled.*	
Pericarp ..	68.52		28.79	
Nuts ..	31.48		71.21	
	100.00		100.00	
Oil	32.45	per cent. fruit.	10.19	per cent. fruit.
Shell ..	16.88		44.39	
Moisture ..	19.71		12.49	
Kernel ..	13.63		26.10	
Fibre ..	16.37		6.11	

From these figures it is seen that the thin-shelled form possesses a far greater percentage of pericarp and oil, and in consequence the percentages of fibre and moisture are higher and the percentage of kernel much less.

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Varieties at Odumase.

At Odumase the variety with fruit green when young instead of black (Twi name "*Abedam*") appears to be very common : much more so than is the case in the Anaji area in the Western Province. Classifying the bunches collected from day to day at Odumase pointed to the occurrence of the different varieties being approximately as follows :—

Thin-shelled forms.	Green form (Abedam).	Ordinary forms. (Abepa, Abetuntum).
6%	19%	75%

In Plot B a thin-shelled form of "Abedam" (one palm only) was observed. This form has not been seen elsewhere and is apparently very rare. A solitary specimen of the "Fetish" or "King" oil-palm also exists in plot B. (*Abehene* Twi *Lalota* Krobo). This is the only variety amongst the oil-palms that has a distinct vegetative appearance : the crown possessing a very shaggy appearance owing to leaflets lacking rigidity and being at a greater angle to the main axis than the other forms.

The mantled type of oil-palm (Diwakkawakka) would appear to exist in Krobo in the Bisa area, judging from information obtained and from actual specimens of fruit procured by the Konor of Odumase from near Bisa. This locality and Kpandu are the only two areas where this interesting form has so far been located : in both areas its occurrence is said to be very rare. No former record of its occurrence on the Gold Coast can be found. Seed of this form obtained from the District Commissioner, Kpandu, has been planted at Aburi.

The Krobo names for the different varieties of oil palm have been found to be as follows.—Twi equivalents given :—

Twi.	*Krobo.*	*Ewe*.*
Abepa	Wie-Kpa-Kpa	Degba
Abetuntum	Wie-Yumu	Deyibo
Abedam	Wie-Hlem	Blede
Abobobe	Wie-Wiam	Aduye
Abehene	Lalota	Klode.

[*The Ewe names were obtained by Mr. A. W. Paterson after Mr. Howes' departure from the Colony. They are the names used in Togoland. The name "KLODE" is used for the Diwakkawakka or "Mantle" type, which is doubtfully reported identical with Abehene. For the present all these names should be regarded as merely provisional.—EDITOR.]

PAPER No. V.

NOTES ON THE STRUCTURE AND CLASSIFICATION OF OIL-PALM FRUITS.

By G. G. AUCHINLECK, M.Sc., F.I.C.,
Deputy Director of Agriculture.

Very little work has been done on the examination and classification of local types of oil-palms. Like many other important matters, this has had to be postponed until an adequate botanical staff has been provided for the Department, and in the meantime we have to rely, for information concerning one of our own crops, on the work of better equipped Departments in the Dutch and British East Indies.

The local classification of oil-palms is based on the colour, shape and structure of the fruit. It is a rough method, and there are wide variations within each recognised type, so that it appears practically impossible to find two palms the fruit of which are exactly alike. The four main types recognised and named locally are :—

Abepa.—(Plate I. figs A, B, C and D, E, F).—Small angular or asymmetrical fruits which ripen a bright yellow-red colour. The proportions shell : kernel : pericarp differ from palm to palm.

Abedam.—(Plate I. figs G., H, I).—Long, ovate fruit which ripen a bright yellow-red colour with a pale-green upper extremity. Proportions shell : kernel : pericarp vary from palm to palm.

Abetuntum.—(Plate I. figs. J, K, L and Plate I.(b) Figs A, B, C).—Ovate, symmetrical fruit, usually of fair size, which ripen to a dark, chocolate-brown colour. Proportions shell : kernel : pericarp vary from palm to palm.

Abehene.—(No specimens secured).—One palm of this type exists at Odumase, Gold Coast. It is doubtfully reported to be of the " mantle " type, that is a compound fruit formed by union of several sterile, oil-bearing flowers around a central fruit. The leaflets are characteristic, lying parallel to the mid-rib with points forward, so that the foliage-crown is quite different in appearance to other types.

In each of these four types there are found individuals which have very thin shells. These thin-shelled sub-types are known as Abobobe, so that there are Abedam-Abobobe, Abepa-Abobobe and so forth. The type shown in Plate II. figs. A, B, C and Plate I.(b) figs A, B, C, are Abobobes of the Abetuntum type.

Normally the oil-palm fruit contains one kernel only, but fruit are frequently found with 2, 3 or 4 kernels. These do not constitute different types but are merely individual variations occurring on the same palm and in the same bunch as normal one-kernelled fruits. As a matter of interest, illustrations of Abedam doubles, triples and quadruples are given in Plate II figs. D, E, F.

Sumatra Types.

The types in Plates I., I(b) and II. were found in the course of a short inspection of the groves at Odumase, Gold Coast. They do not pretend to be complete, and serve merely as the starting point for work on isolation and classification of local types in other parts of the Gold Coast. There is room for a book on the question.

In Plate III. figs. A, B, C, D, E, F, G, H, I, are shewn three types recognised in Sumatra. The illustrations are drawn from A. A. L. Rutgers' " Investigations on Oil Palms, " 1922, and are useful for comparative purposes.

The types figured are as follows :—

Deli.—The standard type on which the whole of the new plantation industry in Sumatra and Malaya has been founded. This type is supposed to have originated in West Africa, but so far has not been found in the Gold Coast.

Lisombe.—A thin-shelled type, which should be a useful starting-point for selecting a strain yielding a high percentage of pericarp-oil.

Mantle.—Known as Diwakkawakka. Possesses a mantle of sterile, oil-bearing flowers massed round a central fertile fruit. Palms of the " mantle " type seen in Java did not show the unusual arrangement of foliage which is said to be characteristic of the Abehene type.

In 1924/5 a series of determinations was made by the Department Chemist, Captain R. Coull, of the average composition of fruits of five local types. The results are given below, with the addition of figures for the Sumatra Deli type for purposes of comparison.

PERCENTAGE COMPOSITION OF FRUIT. MEAN OF TEN SAMPLES OF EACH TYPE.

	Abepa.	Abedam.	Abetuntum.	Abobobe.	Abefita.	Mean for Deli type (Rutgers).
Pericarp-oil ..	21.1	20.7	16.8	33.0	17.7	30.0
,, fibre ..	9.2	9.1	9.4	12.2	7.3	
,, moisture	18.3	17.5	14.1	22.3	14.9	29.5
Shell	37.2	40.1	46.5	19.3	44.1	32.2
Kernel	14.2	12.6	13.2	13.2	16.0	8.3
Whole fruit ..	100.0	100.0	100.0	100.0	100.0	100.0

The Abefita type is not figured in this paper.

Very large variations in the percentage-composition were found, shewing that the local types are not constant in constitution. The extreme variations found among the ten samples of each of these five variations were as follows :—

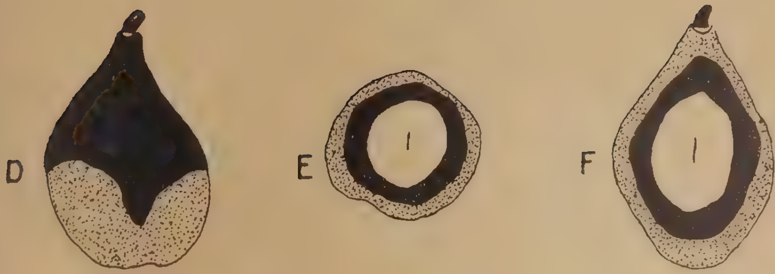
% Fruit	Abepa	Abedam	Abetuntum	Abobobe	Abefita
Pericarp-oil	13.0 to 32.1	8.7 to 39.6	8.1 to 31 7	29.0 to 37.7	13.2 to 22.2
Fibre ..	5.7 to 14.7	2.5 to 15.9	6.1 to 16.0	9.4 to 18.2	4.9 to 9.5
Moisture ..	8.2 to 22.4	9.0 to 25.9	5.5 to 25.6	13.8 to 21.1	7.2 to 18.6
Kernel ..	12.4 to 44.3	25.4 to 45.2	18.4 to 49.4	.8 to 28.2	28.9 to 44.5
Shell ..	7.2 to 26.1	5.6 to 19.2	8.7 to 21.1	7.6 to 17.4	9.7 to 22.2

Conclusion.

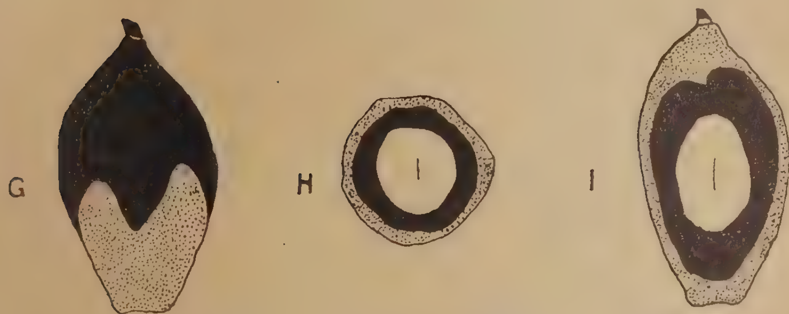
It is hoped that this brief article will shew the need for a careful examination of all local types and for selection and propagation of those strains which promise to be of unusual value commercially.

Work of this sort cannot be systematically continued by officers burdened with routine administrative and investigational work, but unusual types of fruits can be marked and held over for description and classification at some future date when necessary technical staff has been provided by the Government.

PLATE I

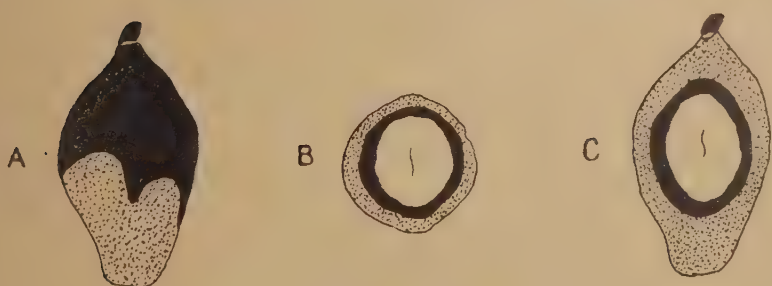


Abepa Oil Palm Fruit



Abedam Oil Palm Fruit

Abetuntum Oil Palm Fruit



Abepa Oil Palm Fruit

Reproduced at Survey H.Q. Accra, 1927.

PLATE IB

Abetuntum - Abobobe Oil Palm Fruit.

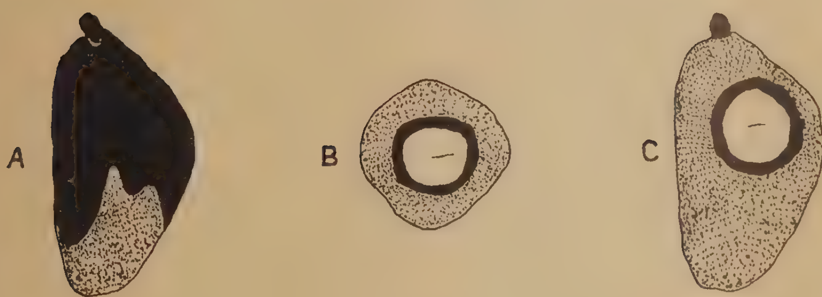


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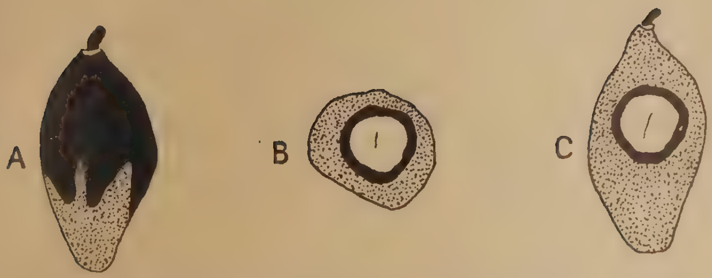
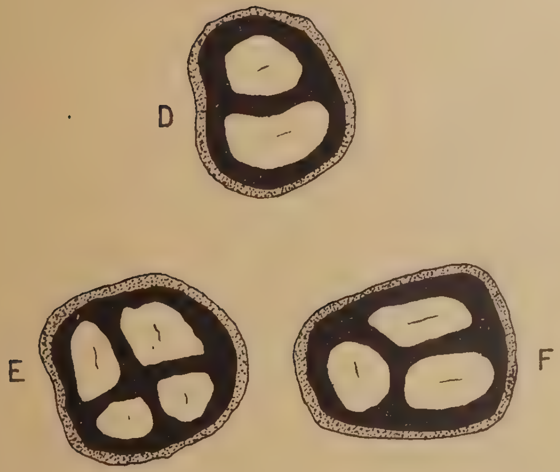
PLATE II

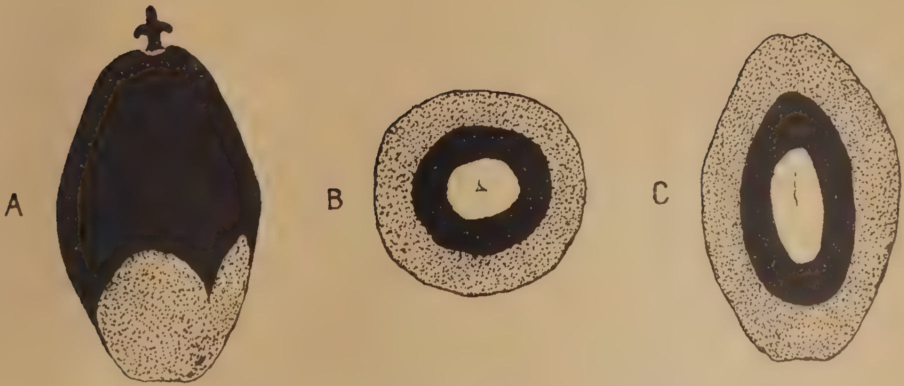


Abetuntum-Abobobe Oil Palm Fruit

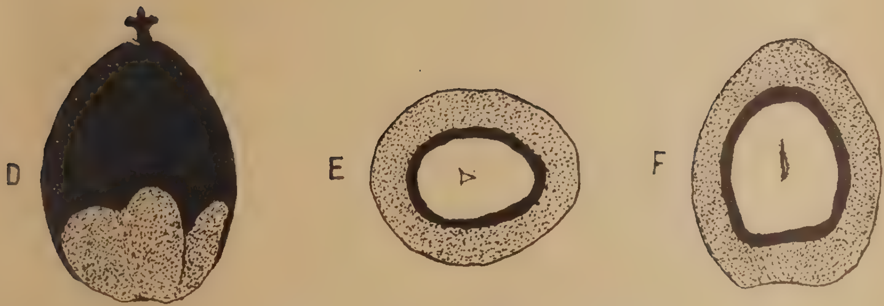


Multiple-Kernelled Oil Palm Fruit
(Abedam Type).

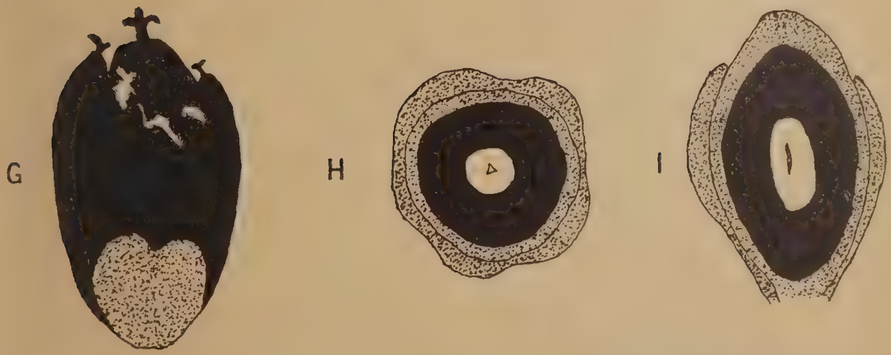
PLATE III



Deli Oil Palm Fruit



Lisombe Oil Palm Fruit



Diawakkawakka or Mantle Type of Oil Palm Fruit

Reproduced at Survey H.Q. Accra, 1927.

PAPER No. VI.

EXTRACTS FROM RECORDS OF THE MYCOLOGICAL DIVISION 1926.

By R. H. BUNTING, F.L.S.,

Assistant Director for Research and Mycologist.

Lime Tree Diseases.

Whilst preliminary investigation of moribund lime-trees in the Central Province resulted in the record of three diseases, it was apparent that the absence of soil-cultivation was largely responsible for the condition of the ten-year old trees.

A number of cases of red-root were found bearing the conidia and rhizomorphs of a *Sphærostilbe* (probably *repens*). Conidial fructifications, rhizomorphs and perithecia (Plate IV. fig. C.,) were also found in masses on a heap of decomposing fruit.

In association with a root-rot, characterised in its early stages by the localised decomposition of affected cortex, there was found in every case a red brown to dark purplish mycelial thread capable of penetrating the soil for many inches without support. No fruiting bodies were found, and efforts to induce infection of young lime-tree roots at Aburi have been unsuccessful. The ultimate condition of an affected root was a sodden mass of decomposed tissue frequently demarcated by scales of the yellow, persistent epidermal tissue.

Cases of die-back too severe to be successfully treated were considered to be directly due to uncongenial soil conditions, they bore numerous saprophytes and in one case *Diplodia*, differing from *Botryodiplodia theobromæ* in size of spores, appeared to be causal.

Stripe Disease of Cocoa Pods.

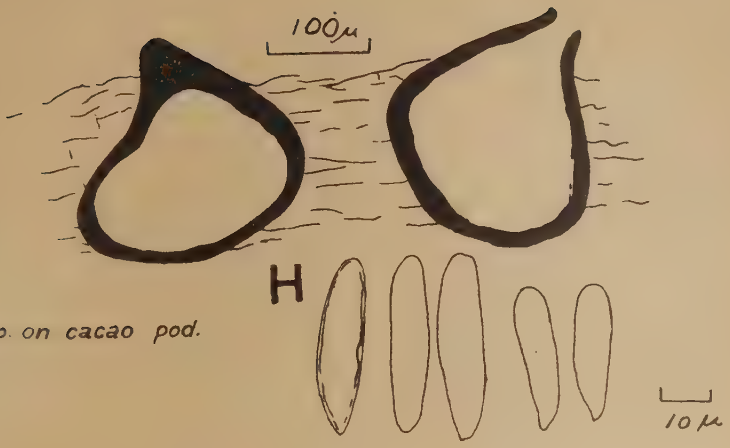
The symptoms of this diseases are external blotchy, reddish brown to black discolorations, arranged longitudinally along ridges on the surface of pod exposed to maximum light; internally the lesions, confined to the pericarp, are at first water-logged in appearance, becoming reddish-brown then slatey and mucilaginous, when they are demarcated by a black border. The sections in Plate VI. figure K shows the disposition of the lesions. The whole pericarp ultimately becomes black and rotten. A bacterium found in the characteristic lesions of this disease is considered to be the wound parasite—*B. aroideæ* Towns.

Other new Records.

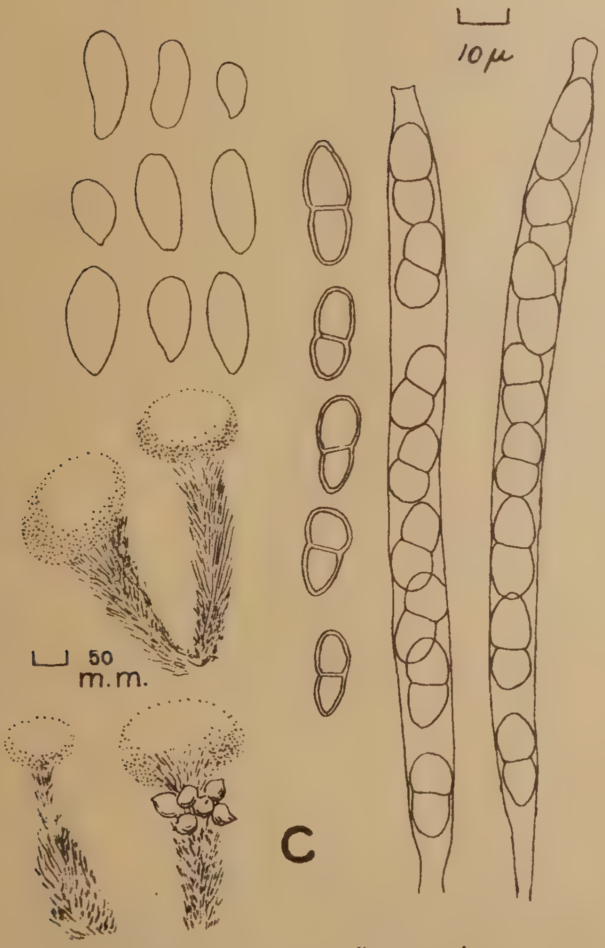
New records of diseases or fungi other than those mentioned above or under "Local Cereal Diseases" are :—

Thielaviopsis paradoxa van Holm on Coconut palms Kumasi.
Ganoderma lucidum Karst. on Cassava, Ejura (Plate V. fig. I.)
Macrophoma sp. on Cocoa pods, Kumasi (Plate IV. fig. H.)
Macrospora sp. on Cotton leaves, Seikwa and Sampa.
Macrosphærella ? *gossypina* on Cotton leaves, Kumasi.

PLATE IV



lacrophoma sp. on cacao pod.



Sphaerostilbe(?)repens on lime roots.

Reproduced at Survey H.Q. Accra 1927.

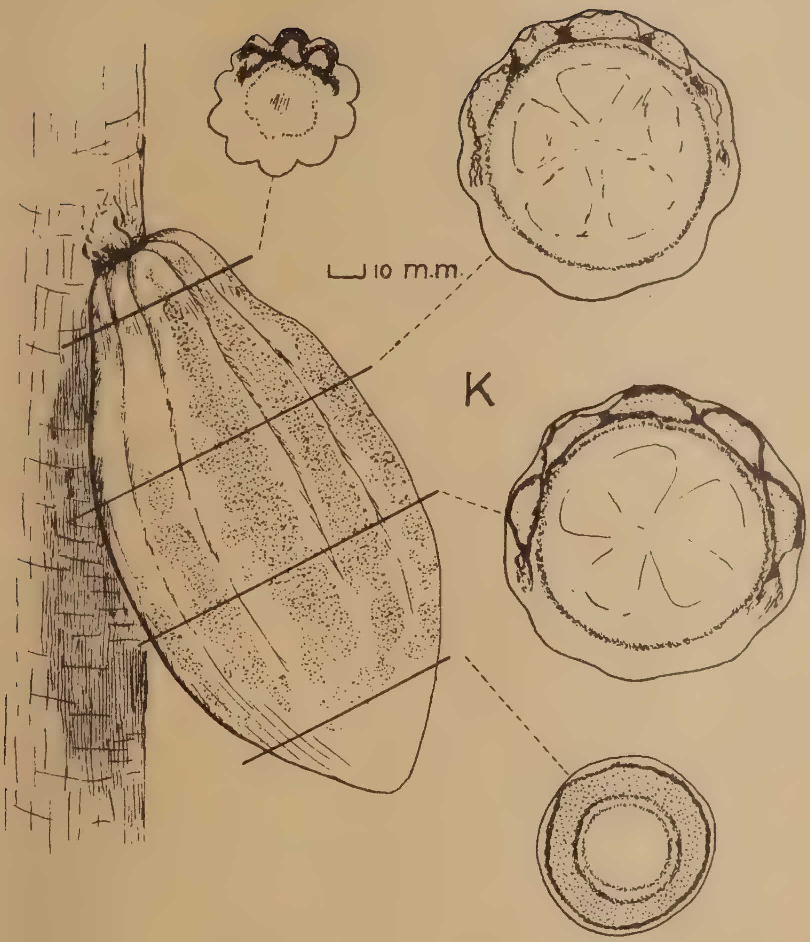
PLATE V

1

Ganoderma lucidum on cassava.

Reproduced at Survey H.Q. Accra 1927.

PLATE VI



Stripe disease of cacao pods.

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PAPER No. VII.

LOCAL CEREAL DISEASES IN THE RECORDS OF THE MYCOLOGICAL DIVISION.

By R. H. BUNTING, F.L.S.,
Assistant Director for Research and Mycologist.

Investigation of the fungi affecting cereal crops has opened up a number of problems requiring elucidation. Of these, the degree of pathogenicity, and the relative economic importance of several fungi, which occur on the staple food crop—maize—, are of interest, as is the question of the possible toxicity to consumers of corn affected by some of the moulds. Species especially requiring attention include *Oospora* (possibly *verticillioides*), *Fusarium* (probably *moniliforme*), *Diplodia macrospora* Earle, *Cephalosporium acremonium* Corda, *Acrothecium lunatum* Wakk., *Basisporium gallarum.*

The frequent occurrence in maize-farms of *Acrothecium lunatum* on leaf-spots, which differ from those caused by the conidial stage of *Ophiobolus heterostrophus* Drechsler chiefly by the occurrence of a translucent central spot, led to an attempt to test the possible pathogenicity of that fungus. The results are not conclusive, but an *Oospora* (Plate VIII. fig. D.), closely resembling the description of *O. verticillioides,* resulted from the inoculation of a maize-seedling—grown on sterilised soil from disinfected seed—with a mildew which developed on separation plates sub-cultured from an *Acrothecium* leaf-spot.

Cultures derived from a case of ear-rot of maize in which the upper part of the host-plant had collapsed by rotting, developed a *Fusarium* considered to be *F. moniliforme* Shel. A suspension of the macroconidia of this fungus was applied to an aseptically cultivated maize seedling, and an *Oospora* (Plate VIII fig. E.), developed, which, whilst morphologically similar to that from the leaf-spot mentioned above, presented certain cultural differences. Opportunity to repeat the tests on a sufficiently large scale is awaited.

Cephalosporium acremonium Corda (Plate VIII. fig F.), has been developed in culture from the discoloured vascular bundles of the peduncle of a nubbin (aborted) cob.

When dehusking cobs of Hickory King corn at Kumasi during the first crop of 1926 a few ears were found to contain greenish-grey to jet-black grains (Plate X. fig. J.), the latter were scattered in groups of 1 to 3 and were found to contain a mass of mycelium

consisting of dark brown, rather thick-walled hyphæ; sub-epidermal pseudostroma bearing several pycnidia were found in the grey grains; the shanks were infested with the same type of mycelium as occurred in the grains and indicated that infection had taken place by the cut end. The fungus agrees with *Botryodiplodia theabromæ* Pat. and has developed typical lesions on cocoa pods.

Acrothecium lunatum Wakk. has been found on the glumes of *Andropogon sorghum,* and on the leaves of *Saccharum officinale* (Plate VIII. figs. B1 & B).

The occurrence of a species of *Marasmius,* believed to be undescribed, parasitic on the leaves of maize, has again been recorded.

A rust—apparently *Puccinia purpurea* Cooke—has been collected on *Andropogon sorghum.*

The following is a list of graminaceous hosts and fungi which have been collected locally :—

Andropogon gabonese Stapf :—
Puccinia sp.

Andropogon Gayanus var. bisquamulatus Hack :—
Capnodium sp.,
Cercospora sp.,
Sphacelia sp.

Andropogon halepense :—
Helminthosporium turcicum Pass.

Andropogon Sorghum L. (Guinea Corn) :—
Acrothecium lunatum Wakk. (Plate VIII. fig. Bl);
Cercospora Sorghi E. & E.,
Colletotrichum andropogonis Zimm.,
Puccinia (prob. *purpurea* Cke.),
Sphacelotheca Sorghi Client.

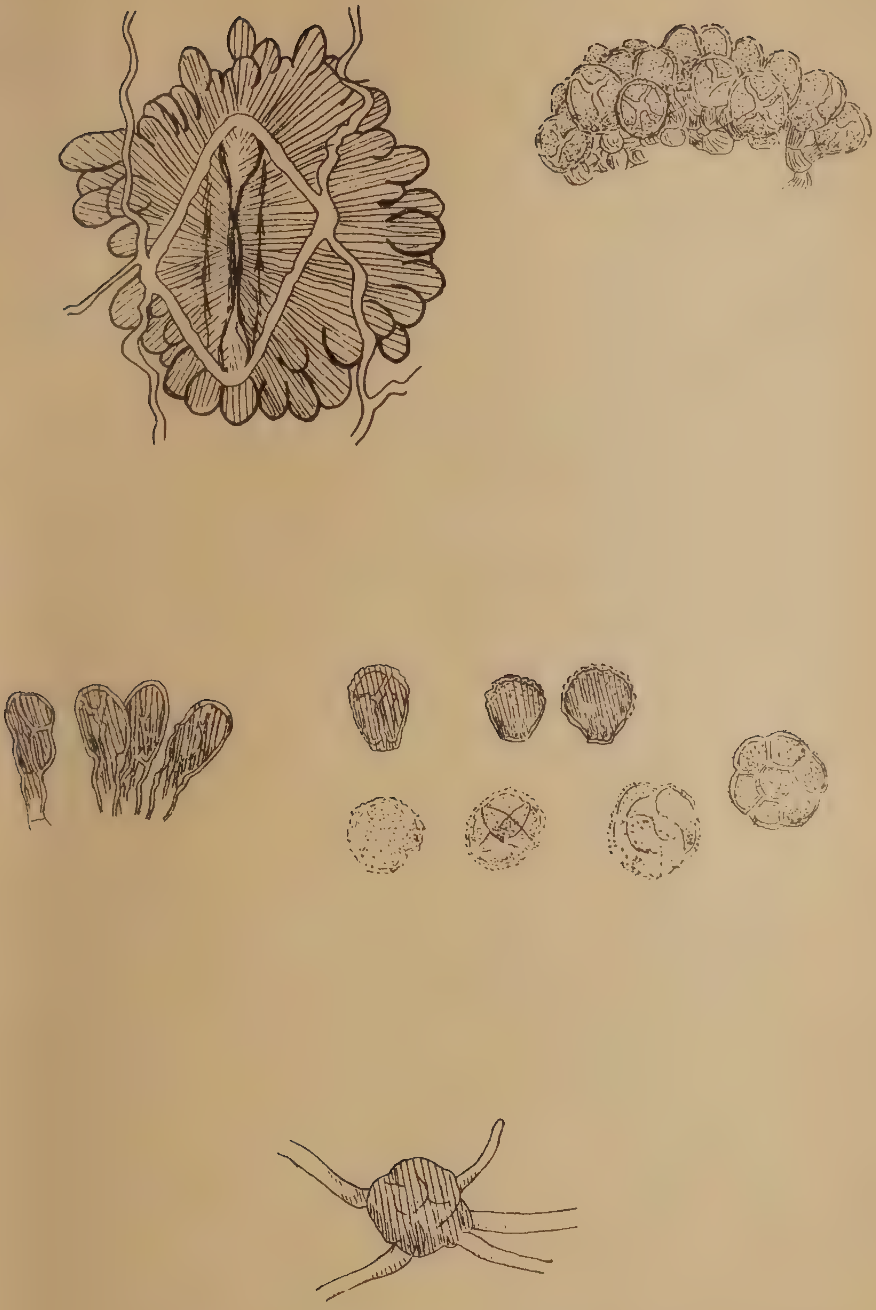
Imperata arundinacea (Lalang) :—
Puccinia rufipes Diet. frequently parasitised by *Darluca filum.*

Mariscus umbellatus :—
Cintractia axicola var. *minor* Client.

Melinis minutifolia (Efwatakala grass) :—
Sclerotium sp.

Oryza sativa L. (Rice) :—
Alternaria sp.,
Helminthosporium oryzæ B. de H.,
Nigrospora oryzæ Petch.,
Piricularia oryzæ Br. & Cav.

PLATE VII

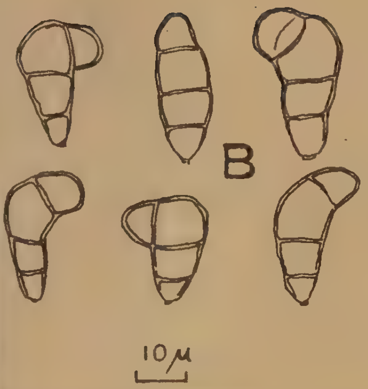


Epicoccum neglectum on Maize-leaves.

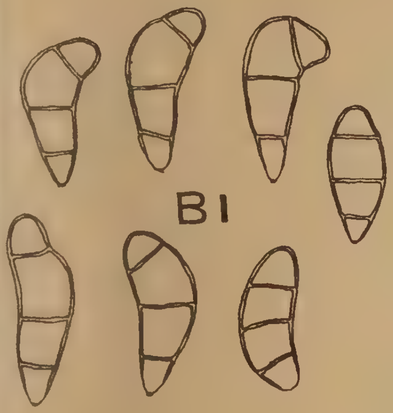
A ⎯ 10μ

Reproduced at Survey H.Q. Accra 1927.

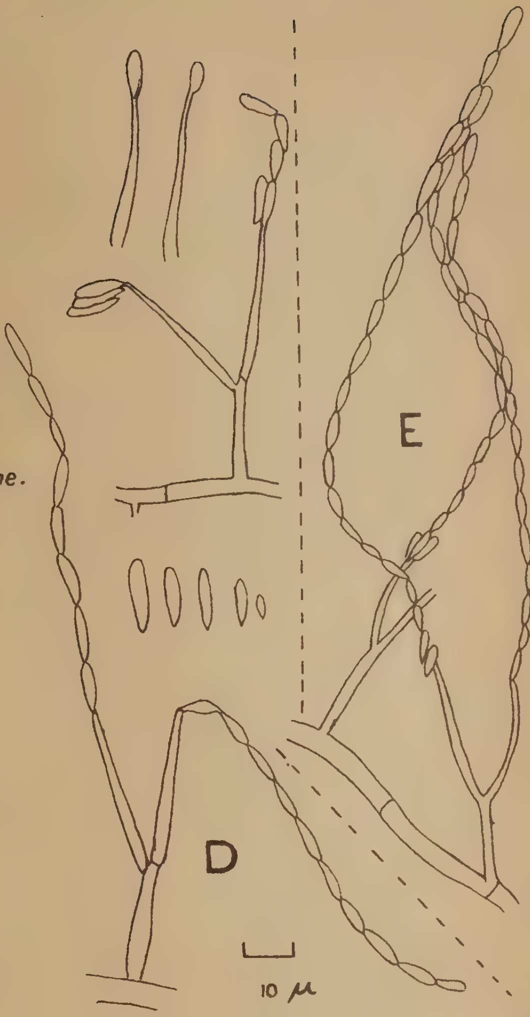
PLATE VIII



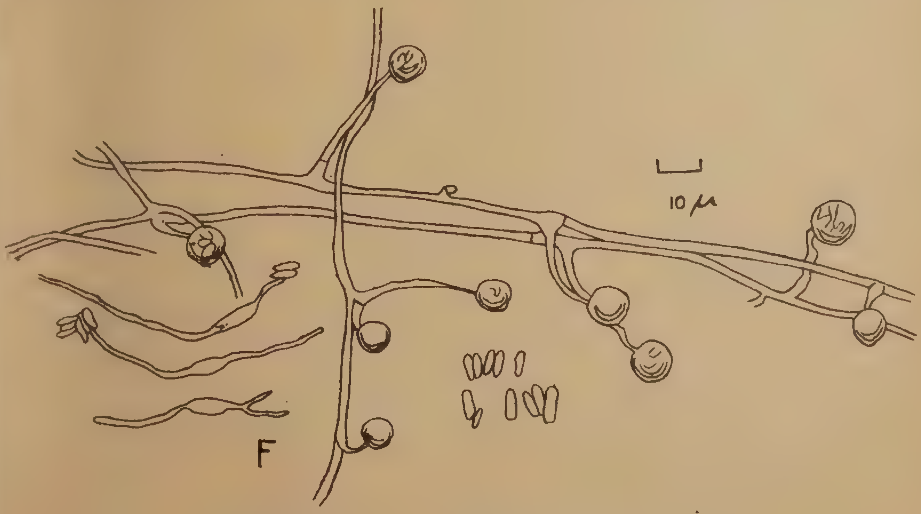
Acrothecium lunatum on Sugar-cane.



Acrothecium lunatum on Guinea-corn.



Oospora sp. from root of maize.

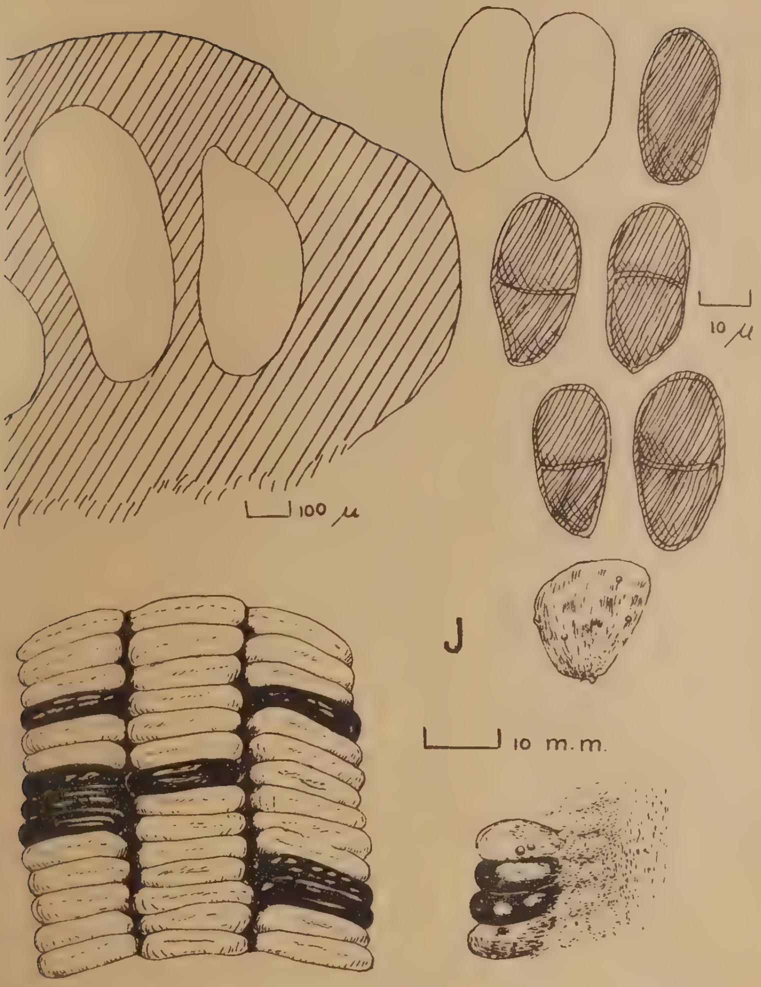


Cephalosporium acremonium on maize.

Reproduced at Survey H.Q. Accra 1927.

Helminthosporium sp. on maize leave.

PLATE X



Botryodiplodia theobromae on maize.

Reproduced at Survey H.Q. Accra 1927.

Panicum maximum :—

Fusarium heterosporum Nees.,
Phyllachora heterospora Henns.,
Ustilago heterospora Henns.,

Pennisetum setosum :—

Cerebella cenchroidis Subram.

Pennisetum typhoideum L. (Bulrush Millet) :—

Helminthosporium sp.,
Puccinia penneseti Zimm.,
Sphacelia sp.,
Tolyposporium penicillariæ Bref.

Rottboelia exaltata :—

Helminthosporium sp.,
Puccinia sp.

Saccharum officinale (Sugar Cane) :—

Acrothecium lunatum Wakk. (Plate VIII. fig. B.)
Helminthosporium sp.,
Leptosphæria sacchari B. de H.

Setaria sulcata Radd. :—

Ustilaginoidea sp.

Sporobolus pyramidalis :—

Epichloe cinerea B. & Br.,
Helminthosporium Ravenelii Curt.,
Marasmius sp.

Urochloa insculpta Stapf :—

Puccinia sp.

Zea mays (Maize) :—

Acrothecium lunatum Wakk. (syn. *Helminthosporium curvulum* Sacc.),
Basisporium gallarum,
Botryodiplodia theobromæ Pat. (Plate X. fig J.),
Cladosporium sp.,
Clasterosporium maydicum Sacc.,
Diplodia macrospora Earle,
Epicoccum neglectum Desm., (Plate VII. fig. A.),
Fusarium (? *moniliforme*.),
Helminthosporium turcicum Pass.,
H. aff. *rostratum* (Plate IX. fig. G.).
H. aff. *sativum*,
Marasmius sp.,
Ophiobolus heterostrophus Drech. (conidial stage only).
Papularia sphærosperma (Pers.) v. Holm,
Pestalozzia sp.,
Phoma zeicola El. & Ev.,
Physoderma zeæ-maydis Shaw,
Puccinia maydis Ber.,
Ustilago zeæ Ung.

PAPER No. VIII.

FACTORS DETERMINING THE INCIDENCE OF DISEASES OF CACAO-PODS.

(Briefly abstracted from Bulletin No 6 of the Department of Agriculture, in which complete data are available.)

BY H. A. DADE, A.R.C.S., *Mycologist.*

A preliminary detailed investigation of cacao pod diseases was undertaken at Anyinam in 1926 in order to obtain definite information from native farms. Such information was not previously available, the only existing records being those of agricultural stations.

At Anyinam, which is situated in the Birim valley in Akyem Abuakwa, an area providing conditions particularly suitable for cacao cultivation, the incidence of pod diseases was known to be very severe. Farms in this district fall into distinct classes, characterised by different conditions of water relation according to their situation on the banks of the river or on higher ground, and according to their relative degrees of lateral and overhead protection. In this brief summary it will suffice to say that from the point of view of the principal factor affecting the incidence of disease —atmospheric humidity—the farms may be classified as of high (excessive), medium and low humidity. From the point of view of the protection of the host plant from the annual drought they may be classified as excessively, sufficiently, and insufficiently protected. The two sets of classes are more or less, but not, necessarily, coincident.

A number of experimental plots were marked out in farms representing each type. The pods on the trees within seven feet from the ground, which it was possible to examine closely, were labelled as they were set, and carefully observed throughout their life, a complete and separate record being kept of each pod. The history of the farms, conditions of shade, drainage, etc., were studied, and meteorological observations were made throughout the season.

Relative Significance of Pod Parasites.

In the farms under observation 55.4 per cent of the total crop was infected by pod diseases. Meteorological conditions in 1926

were less favourable to disease than normal. Different fungi were responsible for these infections, as follows :—

Phytophthora Faberi—" Black Pod "	40.5%
Botryodiplodia theobromæ—" Pod Rot "	6.2%
Colletotrichum sp.—" *Anthracnose* "	0.3%
Trachysphæra fructigena " Mealy Pod "	0.1%
Undiagnosed	8.3%
	55.4%

(Undiagnosed cases were those in which pods were reaped before diagnosis was complete. They were obviously due, the majority to P. Faberi, most of the remainder to Colletotrichum.)

Phytophthora Faberi is, of course, the most important pod parasite. Anthracnose is rather more common than was suspected. The anthracnose fungus—*Colletotrichum sp.* prob. *Cradwickii*, is commonly found as a secondary parasite or saprophyte on diseased pods and husks, and is also found on immature cast-off pods. *Trachysphæra fructigena*, while an efficient parasite of the fruit of Liberian coffee, appears to be only a weak parasite of cacao. It is however found growing very luxuriantly on husk-heaps. *Botryodiplodia theobromæ* appears to be much less important in the Gold Coast than in other cacao-growing countries.

Factors Determining the Incidence of Black Pod Disease.

Humidity.—Of the various conditions which influence the incidence of Black Pod disease, that of atmospheric humidity is the key factor. Records of Relative Humidity were made by reading wet and dry bulb thermometers at 7. a.m. and 2. p.m. in various situations, thereby obtaining a rough but fairly representative idea of conditions of atmospheric humidity during the night and day respectively. Pod records, from observations made twice a week, provided data showing the percentage of healthy pods which became infected during each half-week period. A graphic representation of these results appears in Bulletin 6. In this chart the humidity curve has been set forward 5 days to allow for the incubation period which elapses between actual infection and the first visible symptom—discolouration of the pod. This period occupies from 2 to 8 days, according to the nature of the infection, which progresses more rapidly when it takes place through a wound than when it occurs on a sound pod.

It will be seen that the night humidity curve is fairly flat, which is what we should expect, for in the forest belt the saturation point is reached soon after sunset, and is probably nearly always maintained until dawn. The day humidity curve fluctuates very considerably. In two places on the chart, at H and T, the day humidity is consistently high for a period of a few days, and at these times the incidence-curve rises correspondingly. The minor fluctuations also correspond.

Phytophthora Faberi requires a saturated atmosphere, or a film of water on the pod, for the successful germination of sporangia or zoospores, and infection. Such conditions occur during nearly every night of the bearing season, but in the day only when the Relative Humidity remains high and evaporation from the surface of pods is retarded. This correlation of sustained high humidity and the incidence of infection is clearly shown in the graph in Bulletin 6.

Transmission.—Cacao trees are visited by numerous insects, and these are probably the chief agents of wide transmission. Cultures of *P. Faberi* have been obtained from the feet of insects taken in cacao farms and allowed to walk over the surface of sterile medium in culture tubes. To some extent other animals, and particularly man, also transmit disease. A high degree of incidence occurs in trees by the side of tracks, where spores are carried on the clothing of passersby from diseased to sound pods.

Local Transmission.—It is well known that disease is transmitted by rain or dew-drops falling from diseased to healthy pods on the same tree, and by contact between sound and diseased pods.

In the former case it was found, as might be expected, that the percentage of total infections associated with drip is directly proportional to the relative degree of humidity of the farm. That is, a much greater percentage of the total infections were associated with drip in farms in the high humidity class than in other classes.

On the other hand. about 25 per cent of the total infections were associated with contact between healthy and diseased pods in each humidity class. Here we have a factor dependent on the morphology of the host, and independent of the relative degree of humidity of the farm.

In each case other factors which might affect the data have been examined, which indicate that they do not actually complicate the issue.

Site of Infection.—The influence of the morphology of the host plant was clearly proved. The proportions of proximal, lateral and distal infections were found to be remarkably constant in all the farms, despite the very different conditions prevailing in them.

In each case other factors which might affect the data have been favourable conditions of humidity. Such conditions may be general throughout the farms and in all parts of the pod during the night, but during the day such conditions, while they depend primarily on the degree of atmospheric humidity, are sustained in definite regions of the pod for long periods. Drops of water are retained by surface tension at points where pods are in contact with the trunk or with other pods, and also in the proximal depression surrounding the insertion of the peduncle, and as drips in the distal or lateral regions, according to the posture of the pod. The chances of such retention of water are greatest in the proximal region and least in the distal

region. At these points moisture is held and does not evaporate for a long time, often remaining throughout the day. In the neighbourhood of these drops of water conditions suitable for infection are maintained for long periods, and here the majority of infections take place.

Injury.—Other conditions being constant, damage to the epidermis of pods facilitates infection, although it is by no means a *sine qua non,* for *P. Faberi* is a very efficient parasite and is not dependent upon wounding for its infections. Surface wounds expose the nutritive tissues which otherwise can only be reached by the infection hypha after it has bored through the epidermis. Moreover the exudation of mucilage assists in the retention of moisture which would normally be shed by the waxy cuticle.

Analysis of the various types of injury shows that the wounds which are most frequently followed by infection are those caused by man (cutlass and knife wounds) and pod-borer, the damage done in these cases being extensive. The other insect pests which damage pods are principally Thrips, Helopeltis and Sahlbergella sp. The two former principally infest exposed farms, or parts of farms, *i.e.,* situations where shade or other conditions which affect the constitution of the cacao tree in relation to drought are bad. In such situations atmospheric humidity is comparatively low, and little pod disease occurs. In excessively humid farms such insect damage as occurs causes a higher incidence of infection, but in these farms little damage occurs. With regard to Sahlbergella, attacks by which are not related to conditions of humidity, there is not yet sufficient evidence to show whether the wounds caused by these insects have any considerable influence in the incidence of disease. In dry exposed farms infested with Thrips and Helopeltis statistics shows that there is actually a less degree of infection in wounded pods than in sound ones, but this is because the pods most subject to insect damage are those borne in exposed positions where atmospheric humidity is low.

In farms on which cacao is suitably protected and conditions affecting its well-being are well-balanced, injury appears to have no appreciable effect on the incidence of disease.

Husk-heaps.—Heaps of discarded husks, such as are found in all native farms, have always been suspected as centres of infection during the bearing season, and as nurseries in which disease is carried over from one season to the next.

Much evidence in this case has been collected, and it indicates that husk-heaps as centres of infection are of negligible importance. In the West Indies, in fact, some planters have after trials, decided that sanitary treatment of husk-heaps is not a sound economical proposition.

A few only of the facts elicited by observation need be mentioned here. Figures collected during the season show that there is no definite difference in the percentage of incidence of disease in zones of farms remote from and near to husk-heaps. The first

infections which occurred this season were not related to the site of husk-heaps. In old husk-heaps very few viable spores of *P. Faberi* are present, and it is extremely difficult to obtain a culture from this source.

In fresh husk-heaps *P. Faberi* cannot compete with saprophytes and *Trachysphæra fructigena,* which overrun the husks. Spores of *P. Faberi* are therefore present in comparatively small quantity. At the time when husk-heaps are formed there are numbers of diseased pods on the trees with the fungus in active sporulation, and such pods form an infective agency sufficient to produce all the infections which occur, an agency infinitely superior, on account of their distribution and activity, to husk-heaps. Moreover, from 50 to 70 per cent of the total infections in the farms studied occurred before the formation of new husk-heaps. A study of the economics of the problem shows that the expense of any form of treatment of husk-heaps is out of all proportion to the very doubtful advantage, if any, which may be gained.

Diseased Cushions.—The problem of the means by which the carrying over of disease from one season to the next is accomplished is to some extent solved by the fact that many infections have been found to occur through the peduncle from diseased cushions. Such cushions, exhibiting when opened typical symptoms of canker, were found to be associated with a number of the earliest infections recorded, and with many infections during the season.

Cushion infections account for some of the proximal infections referred to in considering site of infection, but for what proportion is not yet known.

Comparative significance of factors.—A review of all the factors directly affecting the incidence of Black Pod disease shows that, of the total infections studied— over 5,000—the proportions associated with each factor are :—

1.	Contact	25 per cent.
2.	Drip	11 per cent.
3.	Lateral and distal morphology	21 per cent.
4.	Proximal morphology ...	43 per cent.
5.	Diseased cushions	
6.	Injury	trace.
		100

The first four factors could undoubtedly be considerably reduced by controlling the growth of the cacao tree. In native farms its growth is not controlled, and close planting induces the formation of a long trunk on which contact between pod and pod, and pod and trunk is at its maximum. The encouragement of an orchard habit, with a short trunk and a few main limbs, greatly reduces the possibilities of contact, drip and retention of moisture by surface

tension. The production by plant breeding of a strain of Amelonado cacao characterised by a slightly modified morphology would also further decrease incidence of disease to a probably negligible degree.

With a considerable lowering of incidence the further infection of cushions would be automatically reduced, for diseased cushions are undoubtedly the result of previously diseased pods.

The Effect of Disease on the Market Product.

The quality of prepared cocoa is principally determined by the efficiency of fermentation, drying and storage. Pod disease also affects quality to some extent, (i) by the destruction of the mucilaginous tissue surrounding the beans, which supports the yeasts of fermentation; (ii) by the effect of the products of fungus metabolism in which the beans are soaked; (iii) in advanced cases by the actual invasion of the beans themselves by the parasite.

In the first case fermentation experiments show that unless a very large percentage of the fermentation mass is infected, fermentation proceeds normally. That is, the mucilaginous tissue provided by the sound beans present is sufficient for the fermentation of the whole mass.

The effect of fungus excretions on the cotyledons is not yet known.

Some evidence has been collected which indicates that the occurrence of internal moulds in the beans is facilitated by pod disease, although this serious defect is primarily due to incomplete drying or imperfect storage.

Some idea of the cocoa prepared at Anyinam in 1926 was obtained. A number of typical reapings, each yielding about 5 cwts. of dried cocoa, were analysed during the season. It is not possible to estimate the condition of the beans by the appearance of the unbroken pod, and these analyses were made by classifying the beans as each pod was husked.

Very little of the crop was actually lost—*i.e.*, discarded by the farmer, but a great deal of the cocoa prepared was damaged by disease. The "badly damaged" class is that in which the pods were blackened, shrivelled, and more or less dry and hard, while the mucilaginous tissue is either brown and dry, with the beans adhering in clumps, or broken down into black slime. In the latter case the beans are soft and easily crushed between the fingers. There can be little doubt that the quality of such badly damaged cocoa is adversely affected. The "partly damaged" cocoa is that from pods partly or wholly discoloured (brown) in which the mucilaginous tissue is becoming brown, with a tendency to dryness and to adherence of beans.

Thus, while pod disease causes very little actual loss of crop in native industry, it probably has a considerable effect upon quality. At the present time this causes no considerable loss of income to

the farmer, but in the event of a change in market conditions, such as may be expected, the effect of pod disease on quality may assume a greater economic significance.

Effect of Environment on the Periodicity of Cacao.

A remarkable difference in the periodicity of cacao in two types of environment was observed at Anyinam, where some cacao is grown on alluvial riverside flats, subject to annual floods, while other farms are established on higher ground. In the heavily shaded and laterally well-protected farms by the river the main crop is produced and ripened about seven weeks before that of the upland farms. In the former farms the main crop was set from the middle of January to the end of February, and reaping began in the middle of July. In the upland farms fruit was set from the middle of March to early in April, and reaping began in September. In all farms the mid-season crop has become reduced to negligible proportions.

This phenomenon is undoubtedly the result of different conditions of water relation during the dry season. The trees in the upland farms exhibit the periodicity which is normal throughout the country. In the riverside farms, which are very thoroughly sheltered, and in which the water table remains relatively high during the dry season, the physiological processes of the trees are not inhibited by a serious annual drought, and they are able to resume their seasonal activity earlier in the year than are trees in less favoured farms.

Minor variations in periodicity within each class were definitely associated with variations in the environmental factors which determine water relation during the dry season.

Production per Acre in Native Farms.

Our only source of definite information as to yields of cacao in the Gold Coast has been the records of agricultural stations, in which conditions are very different from those in native farms. Careful observations of production on native farms of all types and ages at Anyinam in 1926 showed that the farms produced from at least 8 to 15 cwts. of dry cocoa per acre, the average figure being 11 cwts. (These figures represent the lowest estimate possible, and in every case some of the crop was not included in the counts owing to small reapings which escaped observation.)

These yields are considerably higher than we have previously supposed was the case in native cultivation. They are higher than those of most agricultural stations, but the yields shown in station records do not include the crop "lost" through disease, which is estimated at from 3 to 20 per cent. On stations a great deal of cocoa is discarded which would be included in the crop by a farmer.

Repeated trials showed the number of pods per pound of dried cocoa to be from 6.9 to 10. In agricultural stations the highest record is 8.6, the lowest 20.6. The largest pods were produced in riverside farms.

PAPER No. IX.

NOTES ON TERMITES IN THE GOLD COAST.

(ABSTRACTED IN HEAD OFFICE FROM A REPORT OF W. H. PATTERSON, M.B.E., *Entomologist,*).

In October 1925, a Bulletin (No. 1) of this Department was issued, in which the Entomologist made suggestions for the control of Termites. Since then increasing attention has been paid to the identification of these insects, and the following notes are therefore printed in continuation of the subject.—(EDITOR.)

The following species of termites have been determined by Professor Sjostedt :—

1. *Neotermes aburiensis* Sjost. sp.n. Aburi, 58, 63, from old wounds in cacao trees, having no runways connecting with the soil.
2. *Neotermes sp.n.* Aburi, 67, from living wood in cacao stem, having attacked through a wound. No runway connecting with the soil.
3. *Neotermes sp.n.* Aburi, 68, from similar position to No. 2.
4. *Glyptotermes parvulus* Sjost. Aburi, 69, 71, 72. The first number was from a dry, rotten portion of a cacao branch still attached to the tree, the second from a wound in a living cacao stem, the third from very moist, living tissue of a cacao branch.
5. *Schedothinotermes putorius* Sjost. Aburi, 88, from wide runways up the trunk of *Ficus elastica* previously much injured by the larvae of the cerambicid beetle *Pectognatha gigas* F. Stem of tree much injured by this termite. Similar injury to Flamboyant tree through neglected wound.
6. *Termes (Amplitermes) bellicosus,* Sm. Aburi, 59, a large mound-forming species.
7. *Termes pauperans Silv.* Aburi, 84, 90. This spreads over the surface soil under cover of runways. The nest is subterranean with fairly large fungal gardens and is not easily located.
8. *Termes sudanensis* Sjost. Aburi 85, attacking fallen branches on surfce of soil, nest subaterranean.

9. *Bellicositermes goliath* Sjost. Keta 76. Wide runaway on surface of soil to feed upon debris of wood and vegetable matter. Coming up through crevices in concrete at District Commissioner's court with mound nest beneath bungalow near by.

10. *Termes (Odontotermes)* sp. Aburi, 61, from surface of soil feeding on dead stems.

11. *Microtermes splendens* Sjost. sp.n. Kedji Keta, 79, from the centre of a coconut palm stem, 3 feet above ground, possibly the site of an old wound of rhinoceros beetle.

12. *Enstermes lacifrons* Sjost. Kumasi 73, from old stem wounds in cacao trees; Atitite 81, in dead spathe on a young coconut palm; Atitite 82 from a runway on stem of coconut palm.

13. *Trinervitermes auriterræ* Sjost. Keta, 78, causing injury to base of coconut palm.

14. *Trinervitermes ibadanicus* Sjost, Atitite, 80, from large mound termitarium on Dyson's coconut plantation.

15. *Thoracotermes macrothorax* Sjost, Aburi 89, from a small cylindrical nest, 9 inches high; 91 from nest placed on side of buttress root of a tree.

16. *Hamitermes evuncifer* Silv. var *heterocera* Silv. Aburi, 60, attacking the base of an old palm.

17. *Hamitermes evuncifer* var: *heterocera* Silv. Keta 78, causing injury to base of coconut stem, from the same source as 13. The interrelations were not determined.

18. *Hamitermes unidentatus* Wasm. Kumasi 65, in stem under bark of mango tree with *Coptotermes intermedius* Silv.

19. *Hamitermes unid-evuncifer* var. *heterocera* Silv. Kumasi 62a, from a mushroom-shaped termitarium with superimposed layers.

20. *Procubitermes aburiensis* Sjost. sp.n. Aburi 92, Nest on side of buttress root of same tree as No. 91, Soldiers very scarce.

21. *Cubitermes pallidiceps* Sjost. Kumasi, 61, mushroom-shaped nest with superimposed layers.

22. *Pericapritermes urgens* Silv. *var*. urgens Sjost. Kumasi 62a, from same nest as 18.

23. *Microcerotermes fuscotibialis* Sjost. Kumasi, 66, from a felled and rotten tree. Aburi 74, from a nest in a fork of a tree.

24. *Microcerotermes solidus Silv.* Aburi 70, from narrow runways on cacao stem. Aburi 75, attacking cacao branches through neglected wounds; Keta 77, causing injury to base of coconut stem.

25. *Ancistrotermes crucifer* Sjost. Aburi 62, ascending stems of trees, frequently spreading as a sheath round the stem and feeding on the bark, chiefly the dead material. Aburi 86—with very small fungal gardens scattered over a large area, about 18 inches below the surface. No indication above ground of presence of nest.

26. *Ancistrotermes cavithorax*, Sjost. Dsoje 83, spreading over sticks on soil.
27. *Coptotermes intermedius*, Silv. Kumasi 65, in stem under the bark of mango tree; with ground connection.
28. *Pseudocanthotermes spiniger*, Sjost. Aburi 87.

Termites attacking Cacao.

These are of two classes, those attacking directly from wounds in the stems and having no soil connections, and those attacking from narrow runways up the stems from the soil and thus entering wounds.

Of the first class, *Neotermes aburiensis*, there is no information available as to its prevalence, but it is probably fairly great owing to the lack of care to wounds. The information afforded by Prof. Ballou regarding this type may be given here :—

> " During the last few years a large termite has been attacking " cacao in Grenada, forming a nest or colony that has no con- " nection with another on the ground, or another tree, and " constructing no covered galleries in which to travel from place " to place. The insects invade the trees through wounds where " decay has started, and penetrate into healthy tissue, " often causing severe damage. Attack is *seldom serious except* " *in neglected plantations*, and the remedy lies in cleaning all " old wounds and cutting out all infested wood. All healthy " tissue thus exposed should be covered with a protective dress- " ing such as paint, tar, resin oil or Trinidad crude oil. (*Rev.* " *App. Entomology* IX. p. 516.)

Here in the Gold Coast where there is a noticeable lack of healing tissue over cacao wounds, it may frequently be seen that the wood eventually dies and decays under the coating of tar, and invasion by termites takes place, unless this material is removed. The safest procedure is to periodically retar all large wounds.

As the type of small termites attacking from the soil have no nest which can be fumigated, the best means of control is to see that all wounds are dressed, and that dead material is promptly removed.

Termites attacking Buildings.

From the control point of view these are divided also into two groups—(a) the large mound-forming and (b) those living in the soil, having no easily discovered nest, but forming small fungal gardens over a large area, with minute openings rendering fumigation almost impossible.

Control Measures.

The (a) group can be destroyed by fumigation. Through the kindness of the Chief Entomologist of the American Cyanamid Company, a quantity of calcium cyanide " Dust A ", and other calcium cyanides, together with a " Feeny " foot pump, and duster, were presented for trials.

"Dust A.", contains not less than 40%, and not more than 50% calcium cyanide and is a fine powder, about 80% passing through a 200 mesh screen.

The material was tried with nests of *T.bellicosus*. Holes were made 3 feet apart in the base of the nests, leading directly into the interior of the nest: the dust pumped in for 5 minutes at each opening. Even with openings so close together, not more than 50% of the inmates were destroyed. Using the same kind of pump, R. Owen Wahl, in Pretoria, succeeded in destroying the whole of inmates of $33\frac{1}{3}$% of the nests experimented with, but in this work a much larger quantity of the dust appears to have been used.

With a more powerful pump, a wider distribution of the gas may be affected. As the poisonous effect of the gas is transient and not "cumulative" as in the case of the sulphur-arsenic gas, the destruction of the nest must be thorough, or it may be broken up into a number of small colonies. Consequently at the present stage this method cannot be recommended.

Sulphur-arsenic, used in the proportion of one to four, yielded satisfactory results. It was found necessary to employ oil-palm nuts instead of charcoal in the furnace of the "Four Oaks" White Ant Exterminator, as the pieces of lighter charcoal clogged the discharge nozzle. The former fuel gave off more smoke, useful in locating the surface openings of the nests and indicating the area occupied by the nest; it also afforded a greater heat and thus a greater combustion of the material. The method advised of sprinkling the sulphur-arsenic over the charcoal and quickly securing the lid was found to be wasteful. With the greater heat evolved by the palm nuts, the powder can be placed in a piece of paper or dry plantain leaf. After fumigation it was found that the nests should not be opened for seven days. In some instances this proved too soon, but after ten days all the inmates were dead and the fungal gardens a mass of weeds.

For continuous working the machine is hardly adapted to the work: the defects being (*a*) small furnace, (*b*) incomplete sealing of of lid by the present method employed, (*c*) pump not powerful enough to effect a rapid and wide distribution of the gas.

Work is now in hand for the making of a larger type of Fumigator.

As fear has been expressed that there is a certain amount of risk of accidents from the employment arsenic by untrained workers, efforts are being made to find a less deadly material to handle. So far, sulphur dioxide, used successfully for rat destruction, has not given good results. The makers of the Clayton Fumigator claim a sulphur dioxide generation of an average strength of 15%, against 2-3% from the ordinary methods of producing sulphur fumes. This machine, worked with a powerful fan for distributing the gas, might be of value in this work, and it is hoped an early trial may be possible.

Whilst it has been found fairly easy to destroy the mound-forming termites, for the protection of buildings against the ravages of the small termites success can only be obtained by :—

(a) Destruction of nests in the building area before starting buildings.

(b) Employment of a good type of concrete.

(c) Employment of a course of zinc to project on both sides of the piers or the sleeper walls.

(d) To have no wood resting in a thin layer of concrete.

(e) The substitution of creosote for the solignum at present used.

(f) Impregnating wood with creosote instead of painting with tar or solignum when employed near ground level.

In spite of damage caused to buildings, in no instance has the assistance of this Department been sought when a building has become infested, but arrangements are now in hand for the work on two infested buildings to be supervised, in order to demonstrate to the workmen the care necessary to avoid reinfestation.

PAPER No. X.

LIFE HISTORY AND HABITS, ETC., OF SAHLBERGELLA SINGULARIS HAGL, AND SAHLBERGELLA THEOBROMA DIST.

BY G. S. COTTERELL, A.R.C.S., D.I.C., F.E.S., *Entomologist.*

During the year a Bulletin was prepared entitled "A Preliminary Study of the Life History and Habits of *Sahlbergella singularis* Hagl., and *Sahlbergella theobroma* Dist. (Bulletin No. 3 Dept. Agric.) The following is a summary of the information given in this Bulletin.

There are two distinct species of *Sahlbergella*, the habits of which are somewhat different. Both occur throughout the cocoa belt of the Colony and Ashanti and are known in the former place as " Sankonuabe " and in the latter " Akate ". The Twi name " Sankonuabe " was given to the pests in the early days of cocoa and means " Go back to your Oil Palms ", the production of palm oil being the staple industry of the country prior to the introduction of cocoa. It indicates the importance given to the pests by the native farmer at the time when he was commencing to build up the enormous export crop we have to-day.

Both *Sahlbergella singularis* and *S. theobroma* occur throughout the cocoa-growing countries on the mainland of the West Coast of Africa, being first reported in 1902 from the Kameruns. They were first noticed in the Gold Coast in 1910 and no doubt occurred on cocoa for a long time prior to that date. They are not known in the Portuguese and Spanish Islands of San Thomé and Fernando Po, the oldest cocoa-growing countries of the West Coast of Africa.

Some doubt has been held as to whether both species are indigenous to the mainland of West Africa owing to the lack of natural controls, such as specialised parasites and predators, and the lack of alternative food plants. It was thought that possibly the insects had been imported from San Thomé or Fernando Po in the early days, without their natural enemies which, in the country of their origin, would keep them down to such an extent as to be overlooked as pests. However, certain writers who have made surveys of the insect fauna of San Thomé, particularly insects in relation to cocoa, state definitely that *Sahlbergella* spp. do not occur in S. Thomé. Recently a parasite of *S. singularis* has been bred out at Asamankese (see Paper XI of this Year book), in Akim-Abuakwa, which reaches a percentage parasitism of as much as 8%. It remains to be ascertained whether this parasite occurs in the same proportion in other parts of the cocoa-belt, and also, whether it parasitises *S. theobroma*.

Indigenous alternative food-plants are Silk-Cottons, (*Eriodendron anfractuosum* and *Bombax* sp.), on young plants and suckers of which it can occasionally be observed breeding. It is presumed that prior to the introduction of cocoa, the pests lived on Silk-Cottons and then finding cocoa favourable commenced breeding on that and increased in portion as the area under cocoa increased.

S. singularis has also been observed breeding on *Berryia ammonilla*, an imported plant. It has been stated as having been observed breeding on Cola and Cotton but experiments by the writer have failed to make it breed on these plants.

Life Histories.

The adults of both species are illustrated in Plate XI. figs 1 and 2. *S. singularis* is light brown in colour and speck bad with yellow. The antetennæ are long and the wings large, whereas *S. theosbroma* is black and stouter than *S. singularis* with shorter antennæ and smaller wings. They are more easily distinguished by the colour, size of wings, and the more prominent scutellum of *S. theobroma*.

S. singularis is considerably more active than *S. theobroma* and takes to flight much more readily when disturbed. Both species are sluggish during the day and only take to flight when disturbed. Activity is at its highest in the early morning and evening.

The habits of the two species are different. *S. theobroma* lays its eggs in first and second year wood of young trees under six years old and in the pods, and occasionally in the main trunk near a pod, on bearing trees. In the latter case, pods are only chosen that will not ripen before the resulting nymphs become full-grown. *S. singularis* on the other hand, lays its eggs in the new wood produced by the numerous new flushes of growth of the cocoa plant that occur during the year. Eggs are occasionally laid in pods but this is the exception to the rule. Just prior to and during the fruiting season a large number of nymphs of the latter species are found feeding on pods. These have come down from the newer branches to complete their life on the pods, the latter being more favourable as food. It will be understood that *S. singularis* is a more wide-spread species than *S. theobroma* as there is favourable food for it more or less the whole year round, whereas *S. theobroma* is dependent on young cocoa and developing pods. The result is *S. theobroma* is limited to those areas where there is young cocoa.

The lengths of the egg stage and nymphal instars of both species are more or less the same, the periods being somewhat longer in the case of *S. singularis* than in the case of *S. theobroma*. The average of a number of cage records is given in the table below :—

Species.	Incubation Period.	1st Instar Period.	2nd Instar Period.	3rd Instar Period.	4th Instar Period.	5th Instar Period.	Nymphal Life.	Cycle Egg to Adult.
S. singularis.	16 days	3 dys	3 dys	4 dys	5 dys	(7 dys)	23 days	38 days
S. theobroma.	14 days	3–4 days	3–4 days	4–5 days	4 dys	6 dys	21–22 days	35–36 days

The egg, illustrated in Plate XII., is embedded in the pod or branch by the ovipositor of the female, and lies at an angle of 45° with the surface. Two filaments, one shorter than the other, project from the egg and are the only visible evidence of the egg in the plant. Eggs are laid in groups averaging from 6 to 15, a lesser number being laid each time as the female becomes older.

The nymphal stages of *S. theobroma* are illustrated in Plate XII. The nymphs of each species are distinguished by the slightly darker colour of *S. theobroma* and the shape of the ultimate and penultimate points of the antennæ, those of S. *singularis* being much more elongated than *S. theobroma*. *S. theobroma* nymphs are more robust than *S. singularis* and the latter are flattened in appearance.

Feeding takes place during the early morning and evening, the nymphs of both species taking refuge under pods and in the axils of, and cracks in the branches, during the heat of the day.

An average of from five to six days elapses from time of last ecdysis from full grown nymph to adult female, before eggs are laid, this period being known as the prematurity period. A female *S. theobroma* was observed to oviposit 15 times with a maximum number of eggs of 22 at one time, and to live 27 days during which time she laid 91 eggs. Females were found to be considerably more prevalent in the field than males, although the sexes were bred out in more or less equal numbers in the cages. This is thought to be due to the shorter length of life of the male.

Symptoms of Attack.

Damage is caused by the sucking of the branches and pods and by some substance which is toxic to the plant being introduced at the time of puncturing. In the case of pods damage is localised and is not severe except for the possible secondary infection by pod diseases. Pod damage is illustrated in Plate XIII. Punctures to growing wood result almost invariable in the death of the whole branch, the poison being transmitted to the whole of the branch long after the insects have left. For this reason it is exceedingly difficult to ascertain when the bugs are on the tree. While the nymphs are completing their life-history the only sign of their presence is the wilting of one or two leaves. Two months after they have left, all the leaves have fallen from the attacked branch, and the branch has died back to the older unattacked wood without any further insect attack having taken place. When wood recovers, the scars from the injury remain throughout life as healed up ridges of bark and are usually found at the fork of branches. These are illustrated in Plate XIII.

Certain farms are known to be more or less immune from *Sahlbergella* attack, whereas other, perfectly healthy, bearing farms will suddenly be attacked after a numbers of years of immunity for no apparent reason. It is also known that farms growing in badly drained areas and sandy soil are more prone to attack although

PLATE XI.

Fig. 1.—Sahlbergella singularis. Hagl.

Fig. 2.—Sahlbergella theobroma. Dist.

PLATE. XII

FIG. 1.

FIG. 1 (a)

FIG. 2.

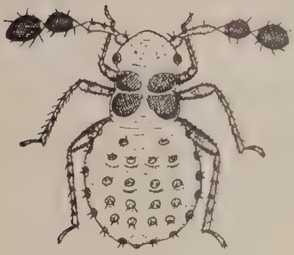


FIG. 3.

FIG 5.

FIG. 4.

FIG. 6.

EGG AND NYMPHAL STAGES OF SAHLBERGELLA THEOBROMA.

Fig. 1.—Egg (enlarged). Fig. 1a.—Showing Egg Filaments projecting from eggs embedded in pod. Fig. 2.—First Instar Nymph. Fig. 3.—Second Instar Nymph. Fig. 4. Third Instar Nymph. Fig. 5.—Fourth Instar Nymph. Fig. 6.—Fifth Instar Nymph.

PLATE XIIa.

FIG. 1.

FIG. 2.

FIG. 3.

NYMPHAL STAGES OF SAHLBERGELLA SINGULARIS.

Fig. 1.—Third Instar Nymph.
Fig. 2.—Fourth Instar Nymph.
Fig. 3.—Fifth Instar Nymph.

PLATE XIII.

Fig. 1.—Appearance of bark subsequent to Sahlbergella attack when branch was young.

Fig. 2.—Appearance of Sahlbergella damage to pods.

PLATE XIV.

Knapsack dusting machine at work on cocoa tree over fifteen feet in height.

attack is by no means confined to them. Trees growing in soils where a red loam is the predominant type are rarely attacked. It is not known whether this is due to the mechanical or chemical composition of the soil. Manuring experiments, and direct feeding experiments on the roots of cocoa trees, carried out since this paper was written, have failed to show any difference in immunity to attack. These experiments are to be repeated, however.

Methods of Control.

Natural controls of both species, as stated before, are limited. Casual predators consists of Mantid nymphs, spiders, lizards and ants, but none of these appears to be any serious check on increase. The importance of insectivorous birds has yet to be ascertained. An internal Braconid parasite, known to occur at the time Bulletin 3 was written, has been bred out in numbers, from *S. singularis* nymphs, since its publication. Details are given of this parasite in Paper XI following.

Cultural controls for the prevention of attack by *S. theobroma* on young farms consist in giving the farm the very best attention during its first six years. This will not make the farm less liable to attack but will result in less actual injury when attack does occur.

Experiments with sprays and dusts have been carried out, but it is considered that liquid spray is absolutely impractical in this country. The feeding habits of the insects being suctorial, a contact poison must be used, *i.e.*, a poison that kills the insect by actual contact and therefore necessitating the insect being covered. To insure this the whole tree must be covered and therefore an enormous amount of insecticide used on a small area. In addition to this, the average hand spraying machine, the only practical type of machine for the farms of this country, is not effective at heights. Every contact insecticide requires the making up of a stock solution requiring a certain amount of skill. Ready supplies of water are also not available on every cocoa farm.

Experiments with nicotine dusts may be practical if the native farmer will take them up. A nicotine dust consist of an exceedingly small amount of nicotine sulphate mixed with hydrated lime, the latter being used as a carrier. An ordinary efficient hand duster can be used to a height of at least 15 ft. effectively. Such a dust is illustrated at work in Plate XIV. Eight to 10 lbs. of dust are required per acre for young trees averaging 5 to 6 ft. height and about 30 lbs. for trees double this height, whereas with a liquid spray 2 gallons will only spray 20 odd trees averaging 5 to 6 ft. in height. A dusting machine will carry 20 lbs. at one charge whereas a spraying machine will only carry 2 gallons. Another advantage of a dust is that no stock solution requires to be made up on the spot.

A nicotine dust is not so efficient as a nicotine spray owing to contact not being so good. However when cost of labour is considered this easily counter-balances the slightly reduced efficiency.

Further experiments are to be carried out on the effectiveness of dusts, particularly with dusts that can be prepared locally.

PAPER No. XI.

A NEW PARASITE OF SAHLBERGELLA SINGULARIS HAGL.

BY G. S. COTTERELL, A.R.C.S., D.I.C., *Entomologist*.

In Departmental Bulletin No 3, "A Preliminary Study of the Life-History and Habits of *Sahlbergella singularis* Hagl. and *Sahlbergella theobroma* Dist.," under the heading "Natural Controls", mention is made of the lack of internal parasites and specialised predators of both species. Mention is also made of a hymenopterous parasite of *S. singularis* found by the writer at Aburi some time ago and also recently at Asamankese in Akim-Abuakwa, and this parasite had not been determined.

Of the few specimens of this parasite obtained at Aburi and Asamankese, only cocoons were obtained and difficulty was met in breeding out adult specimens. Since the completion of the work comprising the subject of this bulletin, further investigations have been made at Asamankese by Mr. E. A. A. Asare, Laboratory Attendant, whilst the writer was on leave. A number of adult specimens, both male and female, have been bred out, and some of these have been sent to the Imperial Bureau of Entomology for determination. Meanwhile it is known by its registered laboratory number 175.

This parasite belongs to the family Braconidæ and a short description is given below. A female is illustrated in Plate XV.

Length (tip of abdomen).—3 to 4 mm.
Width of body (thorax).—1 mm.
Antennæ yellow-brown in colour, long filiform.
Head and thorax black.

Abdomen black, petiolate and in the case of a female, with a protruding ovipositor.

Legs—comparatively long and yellow. Femora of middle and hind pairs of legs are dark brown to black. Tibiæ of middle and hind pairs of legs fitted with short spines at distal apex.

Wings hyaline with large stigma and lined with stout hairs on proximal half of anterior margin of fore-wings.

In the field the parasite has only been obtained from *S. singularis* and not from *S. theobroma*. Laboratory experiments are being put in hand to observe whether it will parasitise the latter species.

Neither oviposition, nor the nymphal period in which this occurs, have been observed. The latter is being ascertained.

The full-grown parasite emerges from the 4th and 5th instar (last two nymphal stages) nymphs of *S. singularis*, followed by the death of the host. Under laboratory condition pupation takes place in the soil just below the surface, but only if the surface soil is moist. It occasionally takes place on the pod or wherever the host has been feeding. In the field cocoons have been found on attacked cocoa pods, but it is thought that as a general rule the weakened host falls to the ground before emergence of the parasite with the result that pupation takes place in the soil. If the surface soil is dry at time of pupation the pupa dries up. This accounts for failure in breeding out adult specimens previously owing to the soil in the cages being too dry.

Before pupation the larva spins a tough cocoon of greyish-white silk about 3 mm. in length. After a pupal period averaging 14 days —minimum 5 days and maximum 18 days—the adult emerges by breaking through one end of the cocoon.

The following table gives percentage parasitisation from May to September, 1926, inclusive, in relation to rainfall :—

Month.	No. of *S. singularis* nymphs collected.—3rd, 4th and 5th instars.	No. of parasitic pupæ obtained.	Percentage parasitisation.	Monthly rainfall in inches.	No. of rainy days in month.
May	135	7	5.2%	5.89	14
June	97	7	7.2%	9.27	19
July	99	1	1.0%	3.40	13
August	131	0	0.0%	1.44	9
September ..	275	21	8.0%	5.88	18

Although the period over which the above records were obtained is far too short to obtain definite correlation between parasitisation and rainfall, it indicates that there may be some correlation. The percentage drops from 7 per cent in June to 0 per cent in August, the rainfall drops from 9.2 ins. to 1.4 ins. during the respective months and increases again to 8 per cent in September with increased rainfall. It is probably not rainfall that affects parasitisation, but the daily range of humidity. Unfortunately humidity records are not taken at Asamankese Station. Further work is to be done on correlation of parasitisation and humidity.

The parasite is obviously a distinct check on the rate of increase of *S. singularis*, but it cannot be said whether its efficiency can be increased until further work is done. However one factor in control is obvious, *i.e.*, retention of rain-forest. *S. singularis* is known to be more prevalent in areas where considerable deforestation has been going on and so increasing the daily range of humidity. This is partly due to the cocoa-plants becoming less healthy and therefore less resistant to insect attack but it is also no doubt partly due to a lowering of the percentage of parasitisation due to climatic conditions being unfavourable to this parasite.

Note :—This parasite has since been identified as *Euphorus Sahlbergellæ*, Wilkinson sp.n., family Braconidæ. It is hyperparasitised by the Ichneumonid *Enesochorus melanothorax*, Wilkinson sp.n.

PLATE XV.

EUPHORUS SAHLBERGELLAE Wilkinson.

A NEW PARASITE OF SAHLBERGELLA SINGULARIS HAGL.

PAPER No XII.

A NEW PARASITE OF HELIOTHRIPS RUBROCINCTA.

BY G. S. COTTERELL, A.R.C.S., D.I.C., F.E.S., *Entomologist.*

During a study of the life history and habits of *Heliothrips rubrocincta,* the Cacao Thrips, at Asamankese last year a minute, internal, hymenopterous parasite, belonging to the family Chalcidæ, was found to form a considerable check during heavy infestations. At present this parasite is awaiting determination.

I have found no record of this insect occurring in San Thomé, where Thrips is a considerably more important pest than it is in the Gold Coast. It is possible that the introduction of this parasite to the former country may form a check on future infestations there.

The adult parasite, which is illustrated in Plate XVI. is 0.7 mm. in length with two pairs of hyaline wings fringed with long hair. The fore-wings have only one vein along the anterior margin. This is characteristic of the family. The thorax and head are black and the eyes dull red. The antennæ are elbowed. The abdomen is light yellow with two dark spots on the dorsal surface, and the legs are yellow.

The full-grown parasitic larva emerges from the pre-pupa of the host, *i.e.*, the penultimate stage before the host becomes adult. Actual oviposition has not been observed but adults have been noticed walking about in colonies of Thrips. Before death the parasitised host becomes sluggish and takes on a pinkish tinge. After death the body of the host becomes cylindrical and two to three days later, the parasite emerges and pupates. The pupa is black and is attached to the underside of the leaf at its hinder end by the dried skin of the host. The pupa lies at an angle of approximately 30° with the surface of the leaf. After eleven days as a pupa the adult parasite emerges.

Parasitism reaches its highest percentage during heavy infestations of Thrips and drops to a negligible quantity when Thrips are comparatively scarce. In a small Thrips infestation, where the colonies are small and scattered, parasitisation does not reach a high figure but in heavy infestations whole colonies on one leaf consisting of fifty or sixty individuals are commonly found completely parasitised. The heaviest infestations of Thrips occur during and after periods of low rainfall. These infestations are gradually brought down to normal by the proportionate increase of the parasite. The parasite, therefore, is most common in September following the decreased

rainfall in August, and also during the main dry season in January and February, reaching a percentage parasitisation of as much as 30% to 40%. Normally it drops to negligible numbers from April to the end of July. In 1925, when the rainfall in the earlier months of the year was abnormal, and the rainfall in June considerably above the average, there occurred a heavy Thrips infestation with a consequent proportionately heavy parasitisation which reached a maximum of between 70% to 80%.

It is probably solely because of this parasite that *Heliothrips rubrocincta* has not become such an important pest in this country as it has done in San Thomé.

PLATE XVI.

A NEW PARASITE OF HELIOTHRIPS RUBROCINCTA.

×37

PAPER No. XIII.

EFWATAKALA GRASS (MELINIS MINUTIFLORA). TRIALS AT KUMASI AGRICULTURAL STATION

By T. HUNTER,

Superintendent, Kumasi Training Centre.

An account of this grass was given in the "Bulletin of The Imperial Institute" Vol. 20, page 300, 1922, as a result of observations made by Mr. M. T. Dawe, when on tour in Angola, pointing out that trials should be made in various parts of Africa with a view to testing its value, both as to its reputed insect-repelling properties, and as a useful fodder grass.

Seed of this grass was received from Kew in June, 1923, and during 1924 the grass was planted over an area of 2 acres, on rising ground leading up from the swamp to the Training Centre. This area was quickly established.

Trials as a Mosquito-Repeller.

In consultation with the Medical Officer of Health, artificial breeding sites were created in and around this area, to obtain information with regard to its use as a mosquito barrier.

The breeding sites were constructed by cutting down cement barrels and placing them in the soil, both within and outside the grass-planted areas, afterwards filling them with water. Artificial shade was provided with palm leaves, and access to the barrels was debarred to frogs, lizards, etc., by covering the mouth of each barrel with small-mesh netting.

Observations made during 1924-5 seemed to indicate that mosquitoes avoided this grass, as only on one occasion were mosquito larvæ found in one of the tubs inside the grass, whereas, in the tubs outside the grass and near the swamp, larvæ were frequently observed.

Further observations were again made during 1926. This year's results prove that the grass had no effect in preventing the breeding of mosquitoes. During June, July, and August, all the tubs contained numerous larvæ. The tubs were emptied at the end of each month, and refilled with fresh water.

Some of these breeding sites were so unnatural, that the evidence conclusively proves the grass to be of little use as a mosquito barrier.

The Senior Sanitary Officer, Dr. P. S. Selwyn-Clarke, who has kindly co-operated in these experiments, entirely agrees with the conclusions drawn, with regard to the absence of barrier qualities in the grass in question

He explains that the absence of breeding last year, may possibly be accounted for by the fact that the collections of water were too recent as far as anopheline mosquitoes were concerned. While so many natural pools were available in the immediate vicinity, it was unlikely that an anopheline would choose an artificial pool.

This year a number of the artificial pools had become much more "natural" as the result of the growth of algæ and other vegetable matter; moreover owing to more effective draining in the swamp area, the number of available breeding places was greatly reduced, so much so, as to render the anopheline mosquito much more dependent upon less natural areas.

The absence of Stegomyia mosquitoes may be accounted for by the relatively small number in the area, and the predilection this type always has for domestic supplies of water *e.g.*, breeding-places closely associated with dwelling-houses, cowsheds, etc.

Only in one instance was Stegomyia found, and that was in the tub nearest to dwelling-houses.

The effect of the grass on tsetse flies could not be tested as no facilities for doing this are available in the vicinity of Kumasi. This would have to be tried in the cattle-breeding area.

Value as Fodder.

The grass appears to have had no ill effect on fruit trees around which it was planted. It is easily eradicated when desired, and from observations made has no toxic effect on the soil; corn and other crops have been grown successfully where the grass was previously growing for two years.

This grass which is easily raised from seed, and readily spreads by runners, was found to compete successfully with other weeds. It is an excellent cover-plant for preventing soil wash, and has also provided large quantities of useful material for mulching purposes.

The yield obtained was approximately 5 tons per acre dry weight.

Its use as a fodder grass was tested by feeding it to cattle arriving in Kumasi from the Northern Territories while awaiting removal to markets.

The grass was fed daily to different cattle each day in both a fresh and dry state, and observations were made over a period of 10 days. The cattle fed on it readily, but showed a distinct preference for the freshly cut grass.

Horses also fed on it readily, both in the stable, and in the field, so that its use as a fodder grass is promising, and it is worthy of extension for this purpose.

PAPER No. XIV.

REPORT ON THE ACCRA SISAL PLANTATION.

BY J. M. WINGATE,
Acting Superintendent.

As this plantation has been established nearly six years, it is now possible to give reliable figures shewing output, cost, yields etc., and the results of the several experiments made.

The adjoining tables shew production and cost for the period 1st April 1925 to 30th September, 1926.

It will be seen from the adjoining table that only three cuttings have been made and as five or six are anticipated a fair estimate of the total yield per acre would be 26 cwts.

PERCENTAGE OF FIBRE IN LEAF.—After several experiments the average percentage of fibre in the leaf was found to be 3.46. This compares very favourably with the percentage obtained in samples grown in other sisal hemp producing countries.

PESTS AND DISEASES.—Very small areas on the plantation were affected by sisal anthracnose (*Colletotrichum agave*) in 1924, but after all diseased plants had been destroyed the trouble disappeared and has not been observed since.

In the same year sun scorch was responsible for the destruction of a considerable quantity of leaf. Specimens of the attacked leaves were sent to the Mycologist, Aburi, who reported as follows :—

" On many of the leaves reddened patches occur which, accord-
" ing to Dowson, who observed the same trouble in Kenya, are
" caused by Sun Scorch in a very wet rainy season. I enclose an
" extract from his paper. "

Dowson (W.J.) :—Some problems of Economic Biology in East Africa.

" (Kenya Colony). . . . . Sisal Hemp (*Agave rigida, var*
" *sisalana*) is also grown in the coastal belt. It has few
" enemies. Ring-spot disease, caused by *Colletotrichum agave*
" Cav. has been recorded in a very wet rainy season. The
" spores of this fungus can be disseminated by air-currents. In
" similar conditions a Sun Scorch nearly always takes place,
" causing large, reddened patches which render decortication
" difficult or impossible. In the season when Ring-spot disease
" occurred a yellow bacterial blotch was found near Nairobi and
" by the amount of gum produced on the tissues, decortication
" was rendered impossible. Sunken yellow areas were pro-
" duced on the upper half of the leaves, varying in size from a

ACCRA SISAL PLANTATION AND FACTORY.

SUMMARY OF PRODUCTION AND COST FOR THE PERIOD 1ST APRIL, 1926 TO 30TH SEPTEMBER, 1926.

Month. 1926	Number of days worked.	Acres Reaped.	Cwts. of Fibre Produced.	Expenditure. £ s. d.
April, ...	21	*A. — *B. 155.40 *C. —	800	706 8 11
May, ...	21	A. 53.00 B. 47.00 C. —	760	702 2 2
June, ...	23	A. 66.00 B. 40.50 C. —	780	674 9 10
July, ...	24	A. 35.00 B. 106.00 C. —	800	759 8 6
August, ...	23	A. 7.40 B. 91.00 C. 64.20	660	718 16 11
September, ..	23	A. — B. — C. 188	820	653 8 10
Totals ..	135	A. 161.40 B. 439.90 C. 252.20 853.50	4,620	4,214 15 2

Spares and eplacements (not charged to any one month) .. 50 19 2

£4,265 14 4

	Days Worked.	Acres Reaped.	Cwts. of fibre produced.	Cost.
Monthly Average	22.5	142.25	770	£710 19 1

Average output of fibre per working days (of nine hours) ..	34.22 cwts.
Average yield (fibre all grades) per acre A. 1st Cutting ..	9.50 "
B. 2nd	4.75 "
C. 3rd	3.10 "
Factory and Plantation Costs of producing one ton of fibre ..	£18 9 3

*A, B and C represent first, second and third cuttings respectively.

ACCRA SISAL PLANTATION AND FACTORY.

SUMMARY OF PRODUCTION AND COST FOR THE PERIOD 1ST APRIL, 1925 TO 31ST MARCH, 1926.

Month.	Number of days worked.	Acres Reaped.	Cwts. of Fibre Produced.			Expenditure.		
			Grade I.	Grade II.	Tow.	£	s.	d.
April, 1925 ..	16	*A. 26.90 *B. —	268	14	38	402	7	0
May, ...	25	A. 22.48 B. 35.00	399	62	39	588	17	7
June, ...	11	A. — B. 36.00	136	18	26	633	9	5
July, ...	24	A. 24.00 B. 48.00	376	80	64	620	3	11
August, ...	20	A. 17.00 B. 25.50	447	40	13	647	14	9
September, ..	2	A. 4.50 B. —	50	—	—	516	8	10
October, ..	0	0	0	0	0	550	1	2
November, ..	13	A. 34.00	352	40	8	640	5	9
December, ..	25	A. 56.00 B. —	727	55	23	772	10	8
January, 1926 ..	24	A. 66.00 B. —	735	50	25	738	10	0
February, ..	21	A. 71.50 B. —	647	55	18	679	3	0
March, ...	24	A. — B. 187.50	808	66	26	759	11	1
Totals	205	A. 322.38	4,945	480	280			
		B. 332.00		5,705				
		654.38				7,549	3	2
Spares and Replacements (not charged to any one month) ..						420	4	8
						£7,969	7	10

	Days Worked.	Acres Reaped.	Cwts. of Fibre produced	Cost.
Monthly Average	17	54.53	475.4	£664 2 4

Average yield (fibre all grades) per acre A. 1st Cutting 12.4 cwts.
B. 2nd ,, 6.9 ,,

Average output of fibre per working days (of nine hours) .. .. .. 27.8 ,,

Factory and Plantation Costs of producing one ton fibre .. £27 18 9

*A, B represent first and second cuttings respectively.

"small speck to a patch several inches in length. Spread "ceased at the end of the rains. The organism—a bacillus— "was isolated and produced the disease by inoculation. It "has not been studied in detail."

The disease on this plantation also occurred after very heavy rains and as was the case in Kenya, spread ceased at the beginning of the dry season.

LABOUR.—Considerable difficulty has been experienced in obtaining a sufficiency of labour for outside work, but on the other hand this difficulty was not found in getting inside labour for factory work.

Labourers are recruited from the Northern Territories and the average supply from this source is 80 per annum.

It was found necessary to increase the rate of pay from 1/6 to 2/- per day in order to attract local labour, and a bonus for good work and regular attendance was also paid at the rate of 5/- and 2/6 per month according to standard of work.

Local labour will always be scarce during the cocoa season and when large building works are being laid down in the Accra district.

EXPERIMENTS.—In the early stage of the plantation the young sisal was intercropped with cassava, but owing to the amount of weeding required for this crop it was found to be uneconomical and was discontinued. It was also observed that the areas intercropped with cassava yielded considerably less than areas where no intercropping took place.

The original 1,000 acres received very careful weeding and consequently the expenditure for this item was exceedingly high, reaching a total of £5 per acre for the first 3 years.

An experimental plot of 40 acres was planted in May, 1925, with the object of finding out whether clean-weeding was absolutely necessary in the growing of sisal. This plot is to receive only 3 weedings during its life (every 6 months for the first eighteen months). If this method is found to be an efficient one the cost of weeding will be reduced from £5 to £2 per acre.

Up to the present this plot has received two weedings in 17 months, and all the plants are healthy and as advanced as areas which have received more frequent weedings.

TASKS.—The following are the daily tasks for the different work on the plantation.

*Planting	250 plants per man.
Heavy weeding	150 plants per man.
Light weeding	250 plants per man.
†1st cutting	65 plants per man.
†*2nd cutting	120 plants per man.
†3rd cutting	175 plants per man.

*Includes the gathering of suckers.

†Includes carrying cropped leaves to the light railway line not more than 175 plants distant.

PRICES REALIZED.—The prices realized in England for the different grades were as under :—

Grade I. £39 to £43 10s. per ton.
Grade II. £36 to £40 per ton.
Tow £25 to £30 5s. per ton.

In conclusion, it may be stated the Government's main object in starting the Accra Sisal Plantation was to try and create a new industry for the people of the Accra plains.

It has been proved that the land in this district, though of little value for the production of food crops, is admirably suited for the cultivation of sisal hemp.

Considering this land has never been cultivated to any great extent and consequently has been of no great value to the African owners, it would seem strange if the Accra people did not make a start now with the growing of sisal and thereby create an industry which is certain to prove a very lucrative one for both farmer and trader.

PAPER No. XV.

YIELDS OF COLA AT KUMASI AGRICULTURAL STATION.

By T. HUNTER,

Superintendent, Kumasi Training Centre.

During 1911 and 1912, 14 acres of forest land were cleared and planted with cola, 25′ x 25′ apart. This area was kept under clean cultivation during the first four years, but the results were not very satisfactory as in 1915 only one-third of the trees were established.

2. A good temporary shade of plantains was then planted and the natural undergrowth allowed to grow between the lines. This treatment proved effective, the plot being completely established during that year. The clearing of the lines and necessary attention to young trees were all that was done until 1921, when the area was gradually cleared, as the trees developed and fruiting increased.

3. Experience on this, and other stations, has proved that growth is slow and disappointing during the early years, unless the young plants are well shaded until they attain a height of 10′. The best results have been obtained where plantations have been formed by planting in lines in the forest, cutting the latter away as the trees developed.

4. The variety grown is *Cola acuminata,* which presumably is synonymous with the *Cola nitida* referred to in various parts of the East.

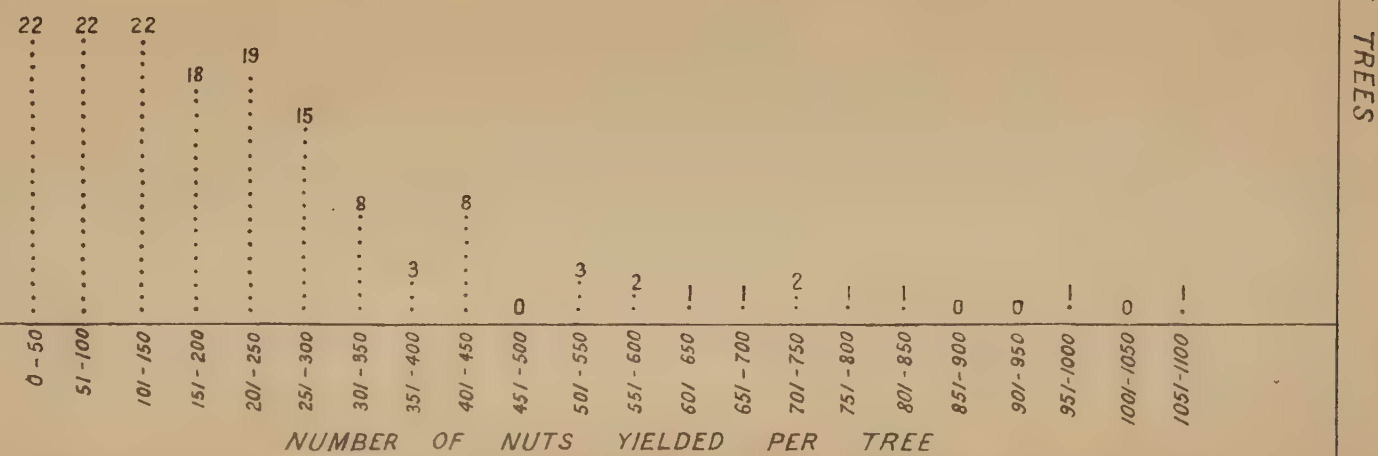
5. During 1923 the area was squared off and the plot reduced to 10 acres.

6. The earlier planted trees began to fruit in 1916, when 19 trees fruited for the first time the number of fruiting trees increasing annually until 1922, when the whole area had reached the fruiting stage.

The cola weevil *Belanogastris colæ,* which is usually so troublesome in destroying a large number of nuts, did not give much trouble until 1924, but this pest is evidently now on the increase, and in 1925-26 destroyed 68% of the crop.

PLATE XVII

CLASSIFICATION OF 150 TREES BY YIELD
CROP 1925–26
COLA AT KUMASI STATION



During the last 7 years, records have been kept of the individual yields obtained from 150 trees, and this record is attached. These trees were not selected but were in one block.

RECORDS OF YIELDS SINCE 1916.

Year.	Area.	No. of trees fruiting.	No. of Nuts reaped.		Total.
			Good nuts.	Bad nuts.	
1916	14 acres.	19 trees.	70	Not recorded.	70
1917	„	22 „	142	do.	142
1918	„	40 „	4.011	do.	4,011
1919	„	41 „	4,500	do.	4,500
1920	„	126 „	4,900	do.	4,900
1921	„	128 „	5,210	do.	5,210
1922	„	Whole plot fruiting.	17,137	do.	17,137
1923	Reducedto10 acres.	„	99,961	do.	99,961
1924	„	„	84,008	45,000	129,008
1925	„	„	41,504	90,603	132,107

In order to summarise the figures in the foregoing Tables, the spotgraph in Plate XVII. has been prepared. The figures used are those for 1925/26, since between the year 1923 and 1924-5 the reaping season was altered and the figures ceased to be returned for the calendar year. Previous to 1923, the trees were not in full bearing.

Inspection of the graph shews that most of these trees yield from 0 to 300 nuts per annum, these classes accounting for 118 out of 150 trees.

INDIVIDUAL YIELDS OF COLA TREES.

KUMASI EXPERIMENT STATION 1919–1926.

Tree No.	Number of nuts (including diseased) per tree.							Tree No.	Number of nuts (including diseased) per tree.						
	1919	1920	1921	1922	1923	1924-25	1925-26		1919	1920	1921	1922	1923	1924-25	1925-26
1	—	—	20	—	54	18	135	28	—	—	—	—	—	—	248
2	—	—	—	—	—	1	19	29	—	23	28	254	280	47	276
3	—	—	—	—	—	6	51	30	—	—	—	43	—	209	518
4	—	26	19	—	847	18	109	31	—	—	—	376	169	317	203
5	—	—	—	652	162	1,358	576	32	—	50	20	54	236	76	114
6	—	—	—	576	160	576	172	33	—	41	38	60	1,937	370	358
7	—	—	—	—	—	10	101	34	—	—	—	104	260	70	153
8	—	—	—	4	79	304	102	35	—	—	—	8	73	270	111
9	—	—	—	—	—	—	58	36	—	—	—	—	—	146	228
10	—	—	—	—	—	12	52	37	—	11	27	200	111	354	334
11	—	—	8	—	696	46	139	38	—	50	24	314	134	468	403
12	—	—	—	—	—	—	—	39	—	—	—	506	45	1,098	162
13	—	—	10	293	26	105	311	40	—	6	20	62	103	308	213
14	—	—	12	122	349	182	269	41	—	—	—	—	—	965	268
15	—	—	—	—	—	113	240	42	—	—	—	—	157	279	248
16	—	—	—	11	15	230	76	43	—	—	—	710	85	585	185
17	—	—	—	62	—	—	—	44	—	—	—	—	—	243	129
18	—	—	—	—	485	189	55	45	—	—	—	243	—	269	224
19	—	—	—	140	170	16	146	46	—	—	13	1,890	695	1,063	253
20	—	—	—	—	144	—	129	47	—	—	18	92	22	948	172
21	—	—	—	17	30	24	130	48	89	—	76	—	71	492	87
22	—	—	15	260	328	5	84	49	—	—	—	—	—	—	50
23	97	—	25	—	42	757	98	50	80	—	106	—	—	—	40
24	—	25	12	112	367	164	100	51	—	—	—	—	—	6	54
25	—	—	—	—	—	13	3	52	—	4	58	38	—	43	409
26	—	—	—	—	—	3	278	53	—	—	—	12	212	1,631	619
27	—	—	—	—	—	—	144	54	—	—	—	162	781	212	147

INDIVIDUAL YIELDS OF COLA TREES.—*continued.*

KUMASI EXPERIMENT STATION 1919–1926.

Tree No.	Number of nuts (including diseased) per tree.							Tree No.	Number of nuts (including diseased) per tree.						
	1919	1920	1921	1922	1923	1924-25	1925-26.		1919	1920	1921	1922	1923	1924-25	1925-26
55	—	—	—	127	88	82	125	82	—	—	—	143	68	208	112
56	—	—	—	141	103	666	412	83	—	—	—	—	—	101	126
57	—	—	—	—	188	703	165	84	—	—	—	—	75	569	69
58	—	—	—	45	—	535	297	85	—	42	57	—	181	46	54
59	—	—	—	—	—	37	57	86	—	—	—	—	167	81	93
60	—	—	—	—	53	56	95	87	—	—	42	—	330	881	53
61	—	—	—	—	—	931	171	88	—	58	100	—	560	2,637	81
62	—	—	—	—	—	619	70	89	—	—	—	—	—	149	151
63	—	—	15	—	124	2,348	180	90	—	—	—	—	906	171	318
64	—	—	—	30	112	85	137	91	—	—	—	508	554	501	261
65	120	50	85	122	1,426	586	151	92	—	—	—	316	891	259	433
66	—	—	—	—	171	210	265	93	—	—	—	396	777	313	418
67	—	—	—	725	128	2,382	664	94	—	—	—	68	—	178	229
68	—	—	4	—	185	248	106	95	—	—	—	—	—	703	264
69	—	—	—	74	—	1,847	256	96	—	—	—	—	240	134	163
70	—	—	—	8	—	—	18	97	—	—	—	—	698	56	60
71	—	4	34	—	—	16	2	98	—	—	—	—	—	259	310
72	—	—	—	31	51	28	25	99	—	—	—	1	—	103	106
73	—	—	—	—	—	—	14	100	—	—	—	—	—	245	741
74	—	—	—	201	—	57	—	101	—	—	—	—	297	617	379
75	—	—	—	—	—	6	46	102	157	21	104	—	47	221	199
76	—	—	—	—	59	3	107	103	—	—	—	214	123	302	168
77	—	—	—	—	43	236	230	104	—	—	25	348	980	1,560	208
78	—	—	—	—	—	15	9	105	—	—	—	—	47	632	212
79	—	—	—	—	277	70	20	106	—	—	28	532	44	769	434
80	—	—	8	—	—	143	65	107	100	71	94	461	—	861	279
81	—	—	—	76	119	458	47	108	—	—	—	376	—	543	168

INDIVIDUAL YIELDS OF COLA TREES.—*continued*.

KUMASI EXPERIMENT STATION 1919–1926.

Tree No.	Number of nuts (including diseased) per tree.							Tree No.	Number of nuts (including diseased) per tree.						
	1919	1920	1921	1922	1923	1924-25.	1925-26.		1919	1920	1921	1922	1923	1924-25	1925-26.
109	—	—	—	—	46	793	301	136	—	—	—	—	—	6	131
110	—	—	—	—	101	661	168	137	—	—	—	177	1,106	205	192
111	—	—	—	6	314	653	301	138	—	—	—	—	27	44	173
12	—	—	—	—	431	222	245	139	—	—	—	—	22	261	801
113	—	—	—	—	486	275	218	140	—	—	—	—	—	4	799
114	—	—	—	—	—	57	212	141	—	—	—	580	—	42	307
115	—	—	—	—	—	112	254	142	—	—	—	1,029	649	425	243
116	—	—	—	—	—	254	232	143	—	—	—	178	58	19	967
117	—	16	49	—	2,167	18	215	144	—	—	—	—	—	219	417
118	—	—	—	—	434	114	250	145	—	—	—	188	22	515	360
119	—	—	—	21	472	71	189	146	—	—	—	365	316	536	739
120	—	—	—	644	488	520	558	147	—	—	—	—	—	457	507
121	75	—	18	624	274	2,490	286	148	—	—	—	40	117	207	26
122	100	241	125	—	—	—	429	149	—	—	—	63	231	260	1,093
123	—	—	—	—	—	36	276	150	—	—	—	—	—	56	535
124	—	—	—	—	—	263	208								
125	—	—	—	—	—	—	317	Means	5	5	9	113	186	331	207
126	—	—	—	262	—	216	45								
127	—	—	—	—	—	606	267								
128	—	—	—	—	—	—	6								
129	—	—	—	7	—	—	33								
130	—	—	—	—	68	—	84								
131	—	—	—	—	—	—	4								
132	—	—	—	—	321	—	120								
133	—	—	2	523	217	50	21								
134	—	—	—	—	—	25	30								
135	—	—	—	—	—	—	59								

PAPER No. XVI.

RESULTS OF TRIALS WITH LIMES (CITRUS MEDICA VAR. ACIDA) IN THE CENTRAL PROVINCE.

BY J. STEELE, M.C., N.D.A., N.D.D.,

Acting Provincial Superintendent of Agriculture, Central Province.

Limes are to be found in small quantities growing over the whole of the Central Province and single trees are comparatively common in most compounds. A lime plot at Asuansi Experiment Station about 3 acres in extent was planted in 1912; the seed apparently came from Aburi from the large fruited or "sweet" lime. Further supplies of lime seeds were obtained from the Agricultural Station at Aburi in 1914-15-16, and were utilised to extend the plot at Asuansi to 13 acres. The limes used to plant this area were of the spiny type.

No serious attempt at establishing lime plantations in the Gold Coast were made until the early part of 1925, when it was decided to induce farmers to plant at least 300 acres in the vicinity of Abakrampa in the Central Province, about 15 miles from the coast-line. The land around Abrakrampa had almost been denuded of forest trees, with the result that cacao planted in this area either died or was abandoned.

It was decided that seed should be sown at stake 12 feet apart. Early in May was considered the best time for sowing, the sowing to be done on two successive days. The Omanhene and farmers in the Abakrampa district were called together and it was explained that 300 acres of land within 4 miles of Abakrampa were required on which to plant limes.

It was explained that the limes should be planted at stake 12 feet apart, that the seed would be supplied free from Asuansi Experiment Station, and that the most suitable farms on which to plant limes were those that had just been planted with corn or yams. It was explained that the limes would be planted in a similar manner to that adopted for cacao by farmers, with the exception that lining should be more carefully carried out. The farmers were asked to prepare stakes about 3 feet in length and 1 inch in diameter, 300 stakes being needed for each acre of cultivation. An Overseer with the aid of a few headmen and local Cacao Instructors went round and lined off each farm; this work was begun in the middle of April, 1925.

In the beginning, the majority of farms dealt with varied in size from $\frac{1}{2}$ an acre to 3 acres in extent and these were scattered over a fairly large area with the result that supervision was difficult. As the farms were lined off a list of farms was made, each farm being given a number, the name of the farmer entered, the number of stakes put in and the position of each farm noted in order that they could be located in the bush. In the early part of May, 1925, sufficient lime seeds were collected from the Experiment Stations in the Colony and the work of planting was commenced; at the end of May approximately 400 acres had been planted, on an average four seed being planted at each stake.

In some cases farmers had a small quantity of seed left; this they were told to sow in a nursery near their farms, in a similar way to that adopted in making cacao nuseries, so that from such nurseries they would have a supply of young seedlings to fill up vacancies.

Germination Tests.

At a discussion held in Accra regarding the planting of limes by farmers at Abakrampa, the question of planting lime seeds at stake, as compared with planting seedlings from a nursery, was discussed. It was the general opinion that lime seeds, like other citrus seeds, quickly lose their vitality and germinative power. In order to obtain information on this point, the following tests were carried out. 2,000 seeds were used during the test; these were prepared by drying in the sun for four days, the pulp removed from the seed-coat by rubbing with charcoal and the seed stored in a tin box with sufficient airholes for ventilation.

100 of these were sown every third day until the supply was exhausted. Results are given in the adjoining Table 1.

It is clear that after 24 days, the loss of germinative-power becomes very rapid, and that half the seeds are valueless after 36 days.

Land on which the Limes were Grown.

The soil on which the limes are grown at Asuansi and Abakrampa varies considerably, from a very light sandy soil in parts to a comparatively heavy reddish clay soil. The land is generally undulating in nature and it has been found that limes grown on swampy and badly drained land do not make much progress. The elevation above sea-level of the land at Asuansi and Abakrampa is approximately 200 feet; the unculating nature of the land is a source of protection against drying winds during the dry season.

The plantation at Asuansi Experiment Station has been laid out at 18 feet apart; seedlings were planted, holes 18 inches cubed having been previously dug for the reception of the young seedlings. Limes planted in 1916 at Asuansi were interplanted with plantains to provide shade for the young lime trees, but in the year 1921 the growth of many of the trees had been retarded owing to the fact that the plantains had overgrown the young limes.

TABLE I.

GERMINATION TEST ON LIME SEEDS AT ASUANTSI.

Successive periods of three days each.	Date Sown.	Date of Germination.	Percentage of seed Germinating.
1st	4-9-25	20-9-25	92%
2nd	7-9-25	23-9-25	74%
3rd	10-9-25	26-9-25	86%
4th	13-9-25	29-9-25	87%
5th	16-9-25	2-10-25	90%
6th	19-9-25	6-10-25	96%
7th	22-9-25	9-10-25	88%
8th	25-9-25	12-10-25	88%
9th	28-9-25	15-10-25	71%
10th	1-10-25	19-10-25	91%
11th	4-10-25	22-10-25	71%
12th	7-10-25	26-10-25	82%
13th	10-10-25	29-10-25	60%
14th	13-10-25	31-10-25	37%
15th	16-10-25	4-11-25	56%
16th	19-10-25	6-11-25	48%
17th	22-10-25	9-11-25	53%
18th	25-10-25	12-11-25	60%
19th	28-10-25	15-11-25	52%
20th	31-10-25	20-11-25	27%

The mean percentage of germination for successive period of 12 days was therefore :—

During 1st 12 days 84.7 per cent.
2nd 12 " 90.5 " "
3rd 12 " 78.7 " "
4th 12 " 50.2 " "
5th 12 " 48.0 " "

At Abakrampa over 620 acres of limes have been planted by farmers, seed being sown at stake. In farms where seed was sown at stake in May, 1925, the young limes have by December, 1926, reached a height of between 3 and 4 feet and there are very few vacancies. The plants are a nice green colour and are vigorous in growth. The average height of the young limes over the 620 acres is probably about 2 feet 6 inches.

The best results have been obtained where farms have been interplanted with yams and cassava; these have been cultivated and incidentally the young limes have benefited by the cultivation. Weeds and rubbish collected during the process of hoeing are placed around the young limes in a circle about 8 feet in diameter, the

farmers having been asked to do this on the approach of the dry season, and in this way moisture has been retained in the soil for the use of the young plants during the drought which lasts as a general rule from the middle of December until the middle of March.

It is important that lime plantations should not be exposed to strong winds, hence farmers have been requested to retain a portion of bush on the windward side of the plantation as a protection. The height of the bush in the Abakrampa district varies from 6 feet to 30 feet, with occasional forest trees and oil palms.

Nursery-Beds.

At Asuansi Experiment Station, where a considerable stock of lime seedlings is usually kept, the nursery soil is of a light sandy nature, and beds are made 4 feet wide, slightly raised to provide drainage. The seed is sown approximately ½ inch apart, in shallow drills, each drill being 1 foot apart. The seeds are protected from the sun by means of a light shade of oil-palm leaves, the seed-beds being kept regularly watered during the dry season. If the seed-beds are made in May or June, little or no watering is required and the young seedlings are ready to plant out about 14 months later. The seed is collected from large fruits and from good bearing trees, and washed with water to rid them of the mucilaginous matter, and charcoal is placed amongst the seeds to dry them: in this way the seed retains its vitality much better during storage and is much more easily handled during planting.

The root system of the young limes is improved if the young seedlings are lifted from the seed-bed and transplanted about 4 inches apart in drills 15 inches apart. At Asuansi the limes are planted 18 feet apart while the limes at Abakrampa have been planted 12 feet. If the limes are too closely planted the branches become intermingled and in a very short time begin to atrophy; these should be removed in order to facilitate the harvesting of the fruit from under the trees. Where the limes have been planted 12 feet apart and it has been found to be too close, in really good heavy soils it will be an easy matter to remove alternate trees.

Yields.

The limes at Asuansi began to bear four years after planting. Those planted in 1916 began to bear in 1920, but profitable yields were not obtained until 1923.

Since 1921 the lime plot at Asuansi has received an annual hoeing, usually at the end of the year just prior to the dry season. During the wet season the whole plot is simply cutlassed. When the trees are fully established and cover the whole of the ground there is very little undergrowth. But the expense of removal of the dead lower branches, equals if not exceeds the cost of cutlassing the bush previously.

Bengal beans (*Mucuna*) have been grown successfully between young lime seedlings at Asuansi. These, being a leguminous crop, increase the nitrogen content of the soil; they grow luxuriantly

and provide an abundance of green material for mulching the young limes, but care should be taken that the beans do not cover the young seedlings.

The lime plantation at Asuansi produces fruit throughout the whole year. But the maximum amount of fruit is usually produced during the months of August and September. The following Table II. shows the monthly yields of fruits from a row of five trees for the years 1922, 1923, 1924 and 1925.

TABLE II.

FIVE TREES—NUMBER OF FRUITS.

Month.	1922.	1923.	1924.	1925.
January	16	40	64	132
February	40	220	102	615
March	424	1,332	1,265	1,212
April	563	1,805	2,569	3,568
May	250	905	169	1,320
June	628	175	780	670
July	810	214	2,690	2,544
August	4,090	3,739	1,900	7,864
September.. ..	8,256	5,500	1,706	7,653
October	2,901	1,942	1,400	1,018
November ..	450	110	180	650
December	54	72	87	246
Total	18,482	16,054	12,912	27,492
Per Tree	3,696	3,211	2,582	5,498

The following Table III. shows the yield of fruit in lbs. from a plot of one acre in area for the year 1926, the trees being ten years of age.

TABLE III.

Month.	Pounds of fruit per acre.
January 1926 ..	236 lbs.
February	391 „
March	1,330 „
April	1,515 „
May	2,338 „
June	2,463 „
July	2,258 „
August	3,296 „
September ..	3,353 „
October	3,898 „
November ..	3,449 „
December ..	3,464 „
Total	27,991 lbs. or 174 barrels of 160 pounds each.

Six samples of lime-juice from these and other local trees were examined by the Chemist during the year. They contained an average of 13.3 ozs. of citric acid per gallon, with extremes of 12.2 ozs. to 14.4 oz. This figure is slightly higher than West Indian figures.

The yield from good plantations in the West Indies is about 150 barrels of fruit per acre, the average being somewhat lower or about 100 to 120 barrels.

Preparation of Concentrated Juice.

A test was carried out at Asuansi Experiment Station in 1924. The fruits were collected from the plantation and placed in cement barrels. Ten barrels of limes were taken, each barrel weighing 150 lbs. Each barrel of fruit produced 5 gallons of raw juice, so that from ten barrels 50 gallons were produced. The raw juice was placed in iron pots and boiled down to one-tenth of its original volume, or 5 gallons.

The costs of gathering and pressing ten barrels of fruit and concentrating the juice obtained is shown below.

Gathering	3/4d.
Pressing	3/9d.
Gathering firewood and firing	3/-.
	10/1d.

Therefore the cost of production of 31 gallons of concentrated juice on the Station would be £3 2s. 10d. The raw lime juice after pressing was strained through a rubber-latex strainer to remove seeds and pulp.

The iron boilers used for concentrating the juice were corroded by the action of the juice during concentration and this had the effect of reducing the acid content.

A cask containing 31 gallons of concentrated juice was shipped to England and the return was as follows :—

1 Cask—31 galls : of 80.50 ozs citric acid per gallon at £20 per 108 galls. of 64 ozs.—£7 4s. 5d.

	Discount 2½%	£0 3 7
		£7 0 10
Analysis	£0 7 0	
Fire Insurance	0 0 3	
Brokerage	0 1 5	
Freight..	£1 6 4	
Marine Dues	0 1 3	
Handling charges	0 19 9	
London Charges	0 1 8	£2 17 8
	Net Proceeds	£4 3 2

Fresh Limes.

Fresh limes have been exported to England on a small scale during the last year. Such limes have been picked when quite green yet fully grown; they are wrapped in tissue paper and packed in aerated boxes. The reports on the shipments exported have been favourable.

PAPER No. XVII.

METHODS OF CULTIVATION AND USES OF THE FOOD CROPS OF THE GOLD COAST.

COMPILED BY E. MARDEN COOK, DIP. AGR. (London).,
Assistant Superintendent of Agriculture.

The following information was collected systematically by many officers of the Department from various districts of the Colony, of whom the following must specially be mentioned :—Messrs Eady, Hewison, Vardy, Martinson, Clerk, Adakwa and Nkpe,—and was compiled at the Department's Head Office.

The question of producing food-crops in the Colony is becoming a very grave one, and it is obvious that the time is not far distant when some steps will have to be taken to produce more food locally and to reduce, or at least prevent the increase of, the present high importation of foreign foods.

The Colony is capable of producing most of its foods as there is a variety of country which is suitable to most crops now imported.

To take two of the most important foods imported, rice and sugar. There is great prospect of the rice industry developinf in Appollonia in the neighbourhood of the Twin rivers. There the soil is similar to that of Sierra Leone, where large areas of swamp-rice are grown. This district alone covers many acres and a Rice Factory has now been erected to deal with the crop.

How much of the sugar cane in the Colony is manufactured into the commercial product ? One sees small areas of cane all over the country and this simply finds its way to the local markets and is sold merely for chewing. Surely if a small area can be grown it can be increased to sufficient size to warrant the erection of a factory which could at least supply the local demand.

The Colony is 91,690 square miles in area with a population of 2,296,400 and the annual value of imports of foodstuffs into the Colony for the past 5 years averages about 3/6 per head of the population.

It is difficult to get out accurate statistics at present as to the yields of the locally grown foods owing to the methods of agriculture adopted by the people, but it is hoped that at an early period provision will be made for obtaining and publishing regular and suitable agricultural statistics.

Dr. J. M. Dalziel, M.D., B.Sc., F.L.S., Deputy Director of the Sanitary Services of the Gold Coast in 1922, gives a complete and comprehensive account of the composition of local foodstuffs together with other useful information on the problem in his article " The Foods and Diet of the Gold Coast People'' Journal of the Gold Coast Agricultural and Commercial Society, Vol. I. No. 4 of July-September 1922, pp. 191-210.

TABLE I.

FOOD CROPS OF THE PEOPLE.

NATURE OF CULTIVATION.

Crop.	Native Name.	Botanic Name.	Time of Planting.	How Grown.	Harvesting.	Yield.
Yam.	Twi—*Ode.* Fanti—*Edwiw* (*Odu*).	Dioscorea alata.	Mar.—April	New areas cleared in Dec. to Feb. and mounds 3″-4″ high are made. Follows Corn, Groundnuts, previous to Cocoa. Interplanted: Plantain, Vegetables, Yams.	6–12 month afterwards. Roots left in the ground to produce yam-heads for seed.	1–3 tubers per mound. 5–12 tons per acre.
Cocoyam.	Twi and Fanti–*Amankani*	Colocasia antiquorum.	Feb.—May first crop. Sept.—Oct. second crop.	Generally planted with Corn, Plantains and Cassava.	Remove as required after 9–12 months.	6–12 tubers per plot. 3–6 tons per acre.
Cassava.	Twi—*Bankye.* Fanti—*Bankyi.*	Manihot utilissima.	Mar.—April Aug.—Sept.	Cuttings inserted in ground after yams or corn and may be inserted for 3 years.	Red varieties 2 years after sowing. White 18 months after sowing.	4 or 5 roots per stand. 4—10 tons per acre.
Groundnut.	Twi—*Nkati.* Fanti —*Nkatsi.*	Arachis hypogea.	Mar.—Apr. July—Aug.	Grassland and old food farms Beds 4″-5″ high are made, seeds sown thickly 1½″ apart to guard against loss. Two crops taken and land reverts.	August—September Nov.—Dec.	6–8 cwt. per acre.

TABLE I.—*contd.*

Crop.	Native Name.	Botanic Name.	Time of Planting.	How Grown.	Harvesting.	Yield.
Bambarra Groundnut.		Voandzeia subterranea.	June—July.	Planted in small patches in the yam farm.	November.	1,000–1,500 lbs. per acre.
Onions.	Twi—*Gyene* Fanti-*Anwiw.*	Allium.	Mar.—Apr. Aug.—Sept.	New land, grown on raised beds 4″ apart in rows 6″ apart.	June—July. Nov.—Dec.	5–6 lbs. per bed of 3′ x 6′ apart.
Sweet Potato.	Twi—*Antomo* Fanti-*Santum.*	Ipomea Batatas.	May—June.	Planted in forest area. Land always ridged after yam crop.	October—November.	125 lbs. 2 tons.
Hausa Potato.		Dioscorea esculenta.	Mar.—May.	On mounds either on new land or old yam land.	Dec.—Feb.	12–15 cwt. per acre.
Tiger nut.	Twi—*Atudwi.* Fanti-*Atadwi.*	Cyperus esculentus.	Mar.—Apr.	Small circular beds in old yam country. 3′ apart 4-5′ between each plant on bed.	July—August.	800–1,000 lbs. per acre.
Corn.	Twi—*Aburo.* Fanti—*Eburo.*	Zea Mays.	Mar.—May. for 1st Crop	Usually on new areas. Ground loosened every 3′.	June—July. 1st Crop.	3 cobs per stand.
			Aug—Sept. for 2nd Crop	3–4 seeds put in. Interplanted with Plantains, Bananas and Cocoyams.	Dec.—Jan. 2nd Crop.	20–50 bushels per acre.
Rice.	Twi—*Emo.* Fanti—*Emu.*	Oryza sativa.	June—July.	Usually broadcasted on swampy land.	December.	720–1,100 lbs. per acre of paddy.

TABLE I.—*contd.*

Crop.	Native Name.	Botanic Name.	Time of Planting.	How Grown.	Harvesting.	Yield.
Millet.	Fanti—*Abom.*	Sorghum spp.	July—Aug.	Planted either on the flat or low broad ridges.	Dec.—Jan.	260–500 lbs. per acre.
Guinea Corn.		Sorghum vulgare	June—July.	Planted on ridges by Mohammedan people on old yam country.	December.	300–400 lbs. per acre.
Beans.	Twi—*Asedua.* Fanti—*Edua.*	Phaseolus lunatus.	Mar.—Apr. July—Aug.	Planted on the mixed areas with other crops: usually under the dead stumps of trees.	July—August. March—April.	4 to 6 bushels per acre in several pickings.
Tomatoes.		Lycopersicum esculentum.	Seeds sown in March and transplanted in May.	Sown in food farms.	September onwards.	10 to 50 per plant.
Peppers.	Twi—*Meko.* Fanti—*Moko.*	Capsicum frutescens, Capsicum annuum.	Mar.—Apr.	Planted in Yam, Corn, Cocoyam and Plantain country.	Aug.—Sept. up to Harmattan.	10–16 bushels per acre in several pickings, one picking makes 1 cig. tin full.
Bananas.	Twi—*Kwadu.* Fanti—*Kodu.*	Musa sapientum.	Feb.—May.	Sown in a yam garden after yams have been planted.	12 months and after.	100–300 bunches per acre.

TABLE I.—*contd.*

Crop.	Native Name.	Botanic Name.	Time of Planting.	How Grown.	Harvesting.	Yield.
Plantain.	Twi—*Brodẹ.* Fanti—*Brodzi.*	Musa paradisiaca.	Feb.—May.	May be planted with yams or corn sown after they have germinated.	12 months after planting and will last 4–5 years.	100–300 bunches per acre.
Papaw.	Twi—*Brofere.* Fanti—*Broso.*	Carica papaya	Appear any time after clearing farm.	Usually sown by birds or in a wild state on food farms.	12 months onwards.	50–100 fruits in a period of two years.
Pine Apple.	Twi—*Abrobe.* Fanti—*Abʌrube*	Ananas sativus.	Mar.—June	Planted in Cocoa or yam farm.	12 months onwards.	1–3 fruit over 2 years
Orange.	Twi and Fanti—*Akutu.*	Citrus aurantium.	During rains.	Planted 15 ft. x 15 ft.	4–5 years old in their prime at 15.	200–700 fruits per year.
Sugar-Cane.	Twi—*Afwereu* Fanti—*Ahyiri.*	Saccharum. officinarum.	Mar.—May.	Planted in marshy soil of lagoons and rivers.	From one year onwards.	15 tons cane per acre.
Coconuts.	Twi—*Kokosi.* Fanti—*Kube.*	Cocos nucifera.		Planted first in a nursery, then out into the plantation when they have germinated.	Sixth year onwards.	30 to 50 nuts per tree. 1,500–2,500 nuts per acre.
Akitiwa Neeli.	Fanti—*Akitiwa*		Mar.—May.	Sown around trees in a yam farm, or corn farm.	9–10 months later.	20–30 fruits per climbing stem. 200–300 plants per acre.

TABLE I.—*contd.*

Crop.	Native Name.	Botanic Name.	Time of Planting.	How Grown.	Harvesting.	Yield.
Bungu.			Mar.—May.	Sown among corn and yams.	Leaves taken when in sufficient quantity. Seeds 4–5 months after.	2–3 lbs. of beans per plant. 1 Cigarette tin full of seed from 8–12 plants.
Lampari.			Mar.—Apr. August.	Usually grown on an old yam farm; after crop the land reverts.	July—August. January—February.	100–200 lbs. per acre.
Sesameim.		Sesamum indicum.	Mar.—April.	On old yam or corn country. Land reverts afterwards.	Leaves plucked when required. 5 months later for seed.	150 lbs. of leaves per acre.
Suley and Rama.			Mar.—May. July—Aug.	Sown on low broad flat ridges in corn farms or round the house compound.	When leaves are required.	

Fruits commonly seen in or near farms include the Hogplum (*Spondias lutea*), the Avocado (*Persea gratissima*), the Mango (*Mangifera indica*), the Guava (*Psidium Guayava*), the Lime (*Citrus medica* var. *acida*), the Soursop (*Anona muricata*), the Sweetsop (*Anona squamosa*), and the Bread-fruit (*Artocarpus incisa*).

Name of prepared food.	Material used.	Method of preparation.
Fufu ..	Yams Plantains Cocoyams Cassava ..	Peeled and boiled. When soft pounded in a wooden mortar, eaten with any soup.
Ampese ..	Yams Cocoyams Cassava Plantains ..	Peeled or unpeeled and boiled; eaten alone or with soup.
Oke ..	Yam Cocoyam .. Ripe-Plantains	Peeled, slice and fried with palm oil.
Kenkey ..	Corn	Quantity required soaked in water, ground the next day between two stones:—Soaked again the next day and ground finally after which the dough is allowed to ferment. Then put portion of dough into boiling water, turn into a pulpy matter, and mix with rest of dough thoroughly. Roll into balls and boil again until well cooked.
Garri ..	Cassava ..	Peeled, grated and put into water. Thoroughly washed and put through a sieve. The mother liquid being allowed to stand. Starch precipitated. The pap after drying is fried to form "Garri." This is eaten with sugar and water or it may be eaten alone or with soup, especially palm oil.
Kokonte ..	Cassava ..	Peeled, split and sun dried. This forms material which is used as a sort of Fufu under the name "gigi."
Tatare ..	Rice ..	Pounded into flour, made into porridge with water, sugar and salt; mixed and eaten.

Name of prepared food.	Material used.	Method of preparation.
Porridge ..	Cassava ..	Peeled, boiled, mashed in water. To this is added salt.
	Corn Millet.. Rice	Ground mixed with water and boiled.
	Yam Cocoyam Sweet Potato Hausa Potato	The same as Cassava.
Soup ..	Palm nut ..	Nuts boiled, pounded in wooden mortar, mixed with water, passed through a sieve and liquid boiled until well cooked. To this is added garden eggs, tomatoes, chillies (ground) and salt.
	Groundnut ..	Nuts roasted gently; when browned, are peeled and ground between two stones. Water is then added to it; put over a fire and boiled until well cooked, adding chillies, garden eggs, and salt.

Use.	Materials used.
As flavouring	Chillies, Tomatoes, Onions.
Eaten raw	All Fruits, Tigernuts, Sugar-cane, Coconuts.
Cooked Vegetables	Tomatoes, Beans, Plantains, Bambarra groundnut.
Eaten roasted	Groundnuts, Corn, Plantain, Bananas, Tubers, Sweet-potatoes, Cocoyams.
Fats	Palm oil, Coconut oil, Shea butter, Nerri, Groundnut oil, Kernel oil.

PAPER No. XVIII.

REPORT ON COTTON SELECTION WORK IN BRITISH TOGOLAND, DEC., 1925-FEB., 1926.

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Cotton selection work was commenced in British Togoland during the 1925-26 season and was carried out at the Agricultural Station at Kpedshu, some 15 miles south of Ho on the Ho-Adidome road. This station may be taken as fairly typical of the cotton growing country of British Togo south of the Bame-Misahohe range; and is situated in open ' parkland ' country with a very unevenly distributed rainfall of 45-50 ins. Before dealing with the different varieties on trial and with selection work in general, a brief account of the history of cotton production in Togoland formerly might not be out of place.

In 1900 the German Colonial Economic Committee despatched a deputation to Togoland to enquire into the question of cotton cultivation in the Colony, and to make necessary recommendations for the establishing of an export cotton industry. This resulted in the employment of an American cotton expert (J. N. Galloway) for a few years to superintend initial developments, and of four coloured men from Alabama to instruct natives as to correct methods of cultivation and handling of the crop. The first experimental station was at Towe where 100 acres were cleared and an agricultural training college incorporated with the experimental work. Later stations were started at Misahohe, Ho, Kpandu, Kete Kratchi, Atakpame and Sokode, indicating that stations were well distributed to serve the various cotton-growing areas. A steady increase in the amount of cotton exported from Togoland during the period 1902-1911 appears to have resulted as following figures indicate :—

1902	80	bales (550 lb. bales).
1903	128	,,
1904	519	,,
1906	857	,,
1907	1,205	,,

Unfortunately figures for subsequent years were not obtainable but considering the estimated export from British Togoland alone for the season 1924-1925 a considerable increase in production has taken place since 1911.

According to records of the varieties grown by the Germans a form of "*Gossypium punctatum*", similar to American Upland types, was found to be very suitable for areas in the neighbourhood of Sokode. Sea Island (*G. barbadense*) was introduced and is reputed to have done very well in the neighbourhood of Agu, Misahohe, and Atakpame. A kidney cotton (*G. brasiliense*) closely allied to Sea Island was grown with success in the Kpandu district. Egyptian cotton was introduced but proved a failure. Several hybrids from the above types were evolved, and for Southern and Central Togoland a form of "G. punctatum x Sea Island" and "G. hirsutum x Sea Island" proved most successful. Final conclusions were to the effect that for Southern Togoland the naturalized Sea Island was most suitable and for the central and more northerly areas American Upland types.

Nature of Cotton at Present Cultivated in British Togoland.

By far the greater portion of the cotton cultivated by the native in British Togoland belongs to that known amongst them as "Soncho" or "Deti-tor" ("deti"—cotton, "tor"—real). This Soncho is without doubt a form of *Gossypium peruvianum* Cav:. It is of vigorous growth frequently reaching a height of 8′—9′ in one season's growth. The staple of this cotton is inclined to be rough though very strong: it is as a rule markedly uneven.

In certain areas in Togoland a cotton closely resembling "Soncho" in general appearance but with the conglomerate or kidney type of seed is cultivated by the natives. This is probably a form of *Gossypium brasiliense* and is derived from seed introduced originally by the Germans and established in the Kpandu district. The relative distribution of "Soncho" and "kidney" cotton in British Togoland is interesting. For the country south of the range of hills running roughly from East to West through British Togoland (Bame to Misahohe) consists almost entirely of "Soncho" (*G. peruvianum*) no trace of "kidney" (*G. brasiliense*) being discernible, whereas on going north of this range "kidney cotton" is immediately encountered and is the dominant type. This state of affairs is in agreement with the statement made by a German trader of Ho (resident in Togoland since 1910) that it was found by the Germans that, roughly speaking, north of this range, which turns in a north-easterly direction on entering French Togoland, kidney cotton was found to be the more suitable, and south of it the Soncho or free seeded (Egyptian) type. Though cotton country north and south of this range might appear superficially to be similar closer observation discloses the fact that certain distinct differences in the vegetation do exist. The Borassus palm for instance—though extremely common south of this range is very rarely encountered north of it, and differences in the proportion of Ctenium to Andropogon species in the grass flora of these two areas are noticeable.

Brown Linted Cotton.

Apart from the above two varieties of cotton—both naked black seeded types—no other cotton can be said to be cultivated seriously by the natives in British Togoland at the present time. No trace whatsoever was seen of the wild tree cotton (*G. arboreum*) reputed as occurring in various parts of West Africa, and it was concluded that if existing at all in Togoland it must be confined to the more northerly areas. A few odd plants of a brown-linted cotton (*G. mexicanum* x *hirsutum ?*) known under the Ewe native name of " Deti-chien " (" red-cotton ") were seen occasionally round native villages ; it is however of little interest as the staple is of poor quality (*vide* lint chart at end) and very short, varying in colour from rust coloured to very light brown. It is commonly stated that the natives esteem small quantities of buff lint for the working of designs but this is rather discredited by the fact that wherever native weaving is witnessed the coloured yarn of whatever colour is always the ready-dyed imported article.

Kadeanyigba.

A small-bolled white linted cotton, with small seed, bearing a white or cream-coloured fuzz was seen on some farms, particularly round Adeklu and Abuadi, though only a few individuals in each farm. This cotton known to the natives as " Kadeanyigba " is probably of *G. hirsutum-punctatum* origin, and the one under native cultivation before the introduction of other forms. It is not now liked by the natives and " Soncho " is everywhere preferred, no doubt on account of the naked seed of the latter and consequent ease with which it can be hand-ginned. In native spinning also it was found preference was expressed for " Soncho ". The lint of this " Kadeanyigba " cotton is of good colour and fine silky texture-fairly strong. The E.C.G.C. has reported well on it as will be seen from their remarks reproduced at the end of this report.

Possible Need of Jassid Resistant Cotton.

A brief visit was paid to the agricultural station at Abor (near Keta) early in December where the cotton was found to be in very poor condition, and appeared to the writer to be suffering severely from the effects of Jassid, particularly the " Soncho " plot. A few odd " Kadeanyigba " plants growing in amongst the " Soncho " were outstanding in having suffered only slightly from Jassid attack. Undoubtedly this is due to the hairiness of the "Kadeanyigba" plant, a strong contrast to the entirely glabrous nature of "Soncho". This is however a matter for the entomologist for authoritative opinion but is nevertheless interesting in that attention is drawn to the fact that it may be necessary to procure a Jassid-resistant cotton for the extreme south-western and coastal areas of the Colony if cotton is to be developed to any extent in them.

Position of Varieties on Trial at Kpedshu.

Owing to the excessive rains at the time of planting germination in the variety test plot was not good and numerous gaps existed throughout, reducing therefore the number of individuals from which

selection could be made. Gaps were most noticeable amongst the Upland types " Meade " and " Allen " and least so in " Soncho " and " Kadeanyigba ". The following variaties were grown at trial at Kpedshu during the season :—

	Variety.	*Origin.*	*No. of Plants.*
1.	Soncho	Togoland	116
2.	Kadeanyigba	,,	167
3.	Deti Chien	,,	67
4.	Meade	Nigeria	16
5.	Allen	,,	22
6.	Zeidabi	,,	40
7.	Kpalagunda	N.Ts.	50
8.	Kummanli	,,	44
9.	Sagai	,,	13

Of the above, several are obviously unsuitable as commercial types and it is proposed to drop them this coming season.

Gold Coast Northern Territory Varieties.—" Kpalagunda " for instance, a red-flowered tree cotton (*G. arboreum* Lim) indigenous to West Africa holds out no promise whatsoever as an annual commercial cotton for several seasons. It is very slow growing with a prolonged ill-defined bolling period and only commences to flower some two or three months after other types. The staple is short and of coarse texture though said to be superior to that of most Indian forms of *G. arboreum*. The habit of the plant is poor, side branches being bunched together and almost vertical : and in appearance distinct from all others, with roselle-like leaves and purple-red flowers. The ginning percentage of this type is very low.

The remaining two Northern Territory varieties are also not promising being of a most straggling habit, the one with buff or rust coloured lint. Whether this straggling habit is but temporarily due to the plants having " gone wild " owing to changed climatic and environmental conditions, or whether this is the natural habit it is difficult to say. The latter probability would seem the more likely. possible contamination might have occurred last year with "Sagai", and " Gummanli " are identical in external appearance (*Gossypium punctatum*, Sch. & Thon., var " *nigerica* "). A difference exists in the lint however, that of " Sagai " being shorter and weaker than that of " Gummanli ", and brown coloured throughout, though the colouration varies from light to dark brown from plant to plant. In " Gummanli "some plants with white and some with brown lint are to be found. The variety is said to be normally white and it is quite possible contamination might have occurred last year with " Sagai ". for the two varieties were grown side by side. The lint of both is short, average measurements from over a hundred readings in each case indicating eleven sixteenths for " Sagai " and thirteen sixteenths to fourteen sixteenths of an inch for " Gummanli ". As already stated neither varieties are promising and it proposed to drop " Sagai " entirely the coming season, but to continue for a while

with "Gummanli" in an endeavour to derive a pure white strain with improved staple length and habit. The comparatively heavy yield of the variety and its fair degree of resistance to boll shedding are the reasons that prompt this decision.

Nigerian Varieties.—The varieties grown from Nigerian seed " Meade ", " Allen ", " Zeidabi " (American Upland types), are superior in lint qualities to other varieties grown, but unfortunately do not seem at all well suited to conditions in Togoland, and are liable to profuse boll-shedding. Germination with these varieties is also bad as will be seen from the Table given on page 5. This state of affairs would appear to be in entire agreement with those in Southern Nigeria, where types such as " Allen " which thrive in the North, cannot be induced to do satisfactorily in Southern Nigeria.

Togoland Varieties.—The type known as " Deti Chien " already mentioned has an inferior brown lint even shorter than that of " Sagai ". The plant itself is very erect with large basal branches, it is however not worthy of consideration and is to be dropped the coming season.

The Togoland variety of " Kadeanyigba ", though little cultivated by the natives at the present time, is well worthy of consideration. The plant is a vigorous grower, bearing a fair number of lateral fruiting branches, and matures reasonably early. Germination is good and the type has the appearance of being well suited to local conditions, with fair immunity to boll-shedding. Selection work with this variety will be carried on extensively.

The remaining Togoland variety " Soncho ", now cultivated by the natives more than any other type, is equally as vigorous as Kadeanyigba and a heavy yielder, though possibly not quite so resistant to boll-shedding. The staple is uneven and on the short side and this will need to be carefully borne in mind during selection. The texture and colour of the lint are slightly inferior to that of Kadeanyigba. The lint of this variety in second and third years growth on native farms was found to average a shorter length than first season's growth : this is referred to later.

Selection Work at Kpedshu.

Selfing.—Inspection of the trial plots on arrival at Kpedshu immediately drew attention to the fact that undoubted cross pollination in some varieties had taken place the previous season, and that immediate steps were necessary to guard against this recurring. Consequently on all the selected plants flowers were " bagged " individually just before opening and the bags removed on the withering of the corollas, *i.e.*, after period of receptivity of the stigmas. By bagging at the right time—in the evening before the morning of opening— and a close tieing of the bags, self pollination is affected spontaneously, in addition to prevention of all chances of cross pollination. On removal of the " bag " from a

faded flower a small label was attached to the pedicel. This was necessary as it was impossible not to miss occasional mature buds, in addition to which many of the plants had already commenced flowering before work at Kpedshu was commenced.

In reaping the yield from each plant, seed-cotton from bolls bearing the tag indicative of self-pollination was kept separate from the rest, and the plants from this seed alone will be used in selection next season. The recording of other bolls was however necessary also in order to ascertain total yield per plant.

Promising Natural Hybrids.—That cross-pollination had taken place last year was indicated particularly in the Upland types where individuals in the "Allen" and "Zeidabi" rows bore buff lint, no doubt through hydridization with one of the brown linted varieties. "Soncho—Kadeanyigba" hydrids, outstanding on account of the shape of the leaves, and intermediate in form and degree of hairiness between the two parents, existed in both "Soncho" and "Kadeanyigba" plots.

Some of the natural "Soncho—Kadeanyigba" or possibly "Soncho—Upland" hybrids were found to have superior lint characters to those averaged by either of the parents. The following list of natural hybrids with lint lengths is interesting, these being some of the nineteen hybrids kept under observation at Kpedshu.

Hybrid	No.	28	yield	70.7 gms.	av. lint length	19.3 sixteenths of inch.
,,	,,	65	,,	180 ,,	,, ,, ,,	16.7 ,, ,,
,,	,,	35	,,	88.6 ,,	,, ,, ,,	18.1 ,, ,,
,,	,,	33	,,	66.4 ,,	,, ,, ,,	17.6 ,, ,,
,,	,,	57	,,	— ,,	,, ,, ,,	17.8 ,, ,,

The figures given above for the yield are of comparative value only, as a few pickings of the plots in which these plants occurred had already taken place before the hybrids were taken under control. Of these hybrids No. 28 is the most promising and will be carefully watched and the more promising of the progeny selfed this season with a view to fixing the type. The nature of the lint of this hybrid No. 28 will be seen from the lint chart attached to the end of this report. It possesses the superior colour and silkiness of the supposed Upland parent and not of the coarser Soncho type. It is also smooth-seeded, which though of no great commercial consideration would render its adoption by the native the more easy, a strong preference being shown by them for smooth-seeded cotton. These hybrids, including No. 28, are mostly large seeded with a somewhat low ginning percentage, running in the neighbourhood of 26%—28%. This is below that of Soncho and American Upland types, but in excess of the native cottons with the exception of "Kadeanyigba" with which it is about equal.

Score Card Adopted in Selection.

Selection was carried out with the following score card as a working basis—

SCORE CARD ADOPTED, BRITISH TOGOLAND 1925-1926.

A.—PLANT.

	Marks.	Total.
I. *Productivity*	15	15
II. *Habit and Earliness of Maturity.*		
a. Erect v. recumbent	2	10
b. Compact v. straggling	2	
Early v. late maturity	6	
III. *Resistance to Pests.*		
Insects	6	10
Fungoid diseases	4	

B.—LINT.

	Marks.	Total.
IV. *Length of Staple*	25	25
V. *Distribution.*		
Very uniform	5	5
Uniform	3	
Fairly Uniform	1	
VI. *Regularity.*		
Very regular	7	7
Regular	4	
Fairly Regular	2	
VII. *Strength.*		
Very strong	8	8
Strong	5	
Fairly strong	3	
VIII. *Ginning Percentage.*		
25—35%	15	15
IX. *Texture and Colour.*		
Good	5	5
Fair	3	
Medium	1	
	Total ..	100

The actual figures for the different varieties are as given overleaf, the columns headed by Roman figures correspond to the factors indicated by corresponding figures on the score card.

SONCHO.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	Total
No. 2	146	34.6	15.9	13	7	7	24	3	7	5	8	5	79
,, 3	151.6	31.3	13.1	14	8	6	2	3	4	5	2	1	45
,, 4	153.5	34.7	14	15	5	7	8	3	4	5	8	3	58
,, 5	111.3	34.9	13.2	2	5	4	4	3	2	3	9	3	36
,, 10	129.5	35.0	13.2	7	9	8	4	1	4	5	10	5	53
,, 11	109.4	33.3	13	0	8	3	6	5	2	3	6	3	36

(Nos. 1, 7, 8, 9, were ruled out on account of shortness of staple and Nos. 6 and 12 on account of fuzzy seed).

KADEANYIGBA.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	Total.
No. 2	158	24.8	15.7	11	7	6	20	5	4	5	6	5	69
,, 4	89	25.5	12.5	6	6	5	4	1	4	3	8	1	38
,, 5	142	26.6	12	10	6	7	3	3	2	3	13	3	50
,, 6	132	26.7	12.1	8	2	3	5	5	4	5	14	3	49
,, 7	128	21.59	11.9	8	4	6	3	5	4	5	2	3	40
,, 10	78	24.24	12.8	6	8	8	5	5	4	5	6	3	50
,, 11	141	26.22	15	10	9	7	18	5	4	8	12	5	78
,, 12	188	—	12.7	15	9	7	5	1	4	5	15	3	64

Nos. 1, 3, 8, and 9 (discarded on account of shortness of staple).

ALLEN.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*III.*	*IX.*	Total.
No. 1	187	28.6	15.5	15	9	8	18	3	4	5	7	5	74
,, 2	165	33.6	12.6	9	10	5	4	3	4	8	15	3	61
,, 3	53.4	30.9	12.7	1	8	6	6	3	2	5	11	3	45
,, 4	166.2	27.5	16.9	8	9	6	25	5	7	5	6	5	74
,, 5	175	25.8	15.5	12	9	8	18	5	7	5	2	5	71
,, 6	108.6	29	15.3	5	7	4	17	3	2	3	8	3	52

ZEIDABI.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	Total.
No. 1	133.9	32.3	13.6	9	7	6	3	5	2	3	13	3	51
,, 2	76.7	31.1	14.1	5	9	3	9	3	2	3	7	5	4[illegible]
,, 3	149.6	32.2	16.6	10	7	5	20	5	7	5	13	3	75
,, 4	95.8	29.7	17.1	6	8	9	24	5	7	5	1	5	70
,, 5	213.1	32.7	14.7	15	10	4	8	3	4	5	15	3	67
,, 6	119	31.9	15.2	7	9	7	17	3	4	3	9	3	62

GUMMANLI.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	Total.
No. 1	85.3	25.3	18.4	15	9	8	24	3	4	3	1	3	70
,, 2	34.9	30.2	12.13	5	8	5	3	3	2	8	15	5	54
,, 4	70.3	26.1	13.8	12	10	5	6	3	4	3	4	3	50
,, 5	39.9	26.02	13.5	7	7	2	5	1	2	3	3	3	33
,, 6	36.1	26.8	13.9	6	8	7	7	1	4	3	5	5	4[illegible]

(No. 3 relinquished on account of shortness of staple).

MEADE.

Yield (gms.)		Ginning %.	Av. Lint Length.	*I.*	*II.*	*III.*	*IV.*	*V.*	*VI.*	*VII.*	*VIII.*	*IX.*	Total.
No. 1	266	26.0	14.1	12	10	6	23	5	4	5	13	5	83
,, 3	214	20.5	12.2	6	6	4	3	3	4	3	1	3	33
,, 5	155	21.7	12.2	1	5	6	3	5	4	3	2	3	32
,, 6	288	27.3	12.6	15	6	4	6	3	7	3	15	3	62
,, 10	225	24.5	13	7	8	7	10	3	4	5	8	5	57
,, 12	180	21.5	11.9	4	5	6	2	3	1	3	2	3	29

As has been indicated it has been decided to drop some of the above varieties this year notably "Sagai," "Kpalagunda," and "Deti Chien."

Cotton of Several Season's Growth.

Several samples of cotton were taken from plants on native farms known to be of two or more season's standing. This was compared with Soncho of one season's growth and was found to be shorter and more uneven (to be expected) as can be seen from the following figures.

The figures in A represent staple-length measurements of lint drawn from 12 different plants on native farms of two and three years standing, whereas those in B represent staple-measurements of lint from plants in their first season's growth.

A.

No. 1	(12.12.12)	(11.13.11)	(13.13.13)		
,, 2	(10.12.12)	(13.12.12)	(12.13.12)		
,, 3	(13.12.14)	(13.14.13)	(14.15.14)		
,, 4	(10.11.10)	(10.13.10)	(9.11.9)		
,, 5	(14.12.13)	(12.13.14)	(12.13.12)	*Average*	12.19.
,, 6	(8.9.8)	(8.9.8)	(8.8.8)		
,, 7	(14.14.13)	(12.13.11)	(12.12.13)		
,, 8	(13.14.14)	(15.13.14)	(14.14.15)		
,, 9	(9.11.10)	(7.12.9)	(9.10.10)		
,, 10	(14.12.15)	(14.12.13)	(13.14.12)		
,, 11	(17.17.16)	(17.14.16)	(16.16.15)		
,, 12	(15.14.13)	(12.13.14)	(12.14.15)		

B.

No 1	(11.12.11)	(12.12.12)	(12.11.12)		
,, 2	(10.12.10)	(10.12.10)	(12.10.10)		
,, 3	(11.11.10)	(10.12.10)	(12.11.14)		
,, 4	(13.13.14)	(14.12.14)	(14.13.14)		
,, 5	(14.15.14)	(14.11.14)	(11.14.14)	*Average*	13.12.
,, 6	(14.14.16)	(14.16.14)	(12.13.14)		
,, 7	(16.15.15)	(15.16.16)	(15.16.16)		
,, 8	(14.12.12)	(14.13.15)	(15.13.15)		
,, 9	(12.16.12)	(12.15.12)	(13.14.13)		
,, 10	(13.12.11)	(12.13.12)	(12.12.12)		
,, 11	(13.13.14)	(14.14.15)	(15.15.15)		
,, 12	(10.12.12)	(12.14.14)	(12.12.12)		

Report for the E. C. G. Corporation on Togoland Cotton.

In February two small consignments of "Soncho" and "Kadeanyigba" cotton grown in Togoland were forwarded to the Empire Cotton Growing Corporation. The lint, from plots on the station, was carefully hand picked to remove all stained cotton. A copy of the Empire Cotton Growing Corporation's reply is reproduced below from which it will be seen that

the qualities of the two lints (when free from stainer) are fair, though still on the short side. According to the broker's report "Kadeanyigba" lint is superior to "Soncho" the respective values being 11.15d. and 10.25d. based on March American futures at 9.5d.

It must not be lost sight of that these samples had all been picked free of stained cotton and that the normal native-produced cotton from Togoland with leaf and stained cotton in varying quantities would not be valued at these figures. However it indicates that the present cotton grown in Togoland when clean and stain-free is capable of realizing a good price, and that the elimination of stained cotton and instruction of the natives in clean-picking are probably quite as important as the establishment of superior longer linted types of cotton in Togo.

EMPIRE COTTON GROWING CORPORATION.

Millbank House,

2, Wood Street,

Millbank,

London, S.W.I.

25th March, 1926.

DEAR SIR,

I have to acknowledge with thanks the receipt of your letter of the 23rd ultimo under the above reference number. The samples of cotton duly arrived, and I have now received a report on them from Messrs. Wolstenholme and Holland, who are one of the most important brokers in Liverpool who deal with Empire-grown cottons. The samples are too small for spinning tests to be carried out upon them.

You will see from Messrs. Wolstenholme and Holland's report that sample B. is valued at 90 points on the value assigned to sample A. and that both are worth more than American futures. We shall be interested to hear the results of the trials with your selections from A. and B. which you are carrying out this season.

Yours faithfully,

L. G. KILBY,

Secretary.

WOLSTENHOLME & HOLLAND,
LIVER CHAMBERS, TITHEBARN STREET,
LIVERPOOL, *23rd March*, 1926.

Mr. J. C. MAY, Messrs., The Empire Cotton Growing Corporation, London.

DEAR SIR,

We consider the value and description of your Cotton samples from the Gold Coast..............to be this day as follows :

Mark.	Quality.	Description.	Value.	Classification &c.
A.	(Soncho).		10.25d.	Indigenous character, light brown in colour Staple rough full $1\frac{1}{8}''$ fairly strong.
B.	(Kadeanyigba).		11.15d.	American character, Staple fairly fine and strong, about 1.1/16" @ $1\frac{1}{8}''$.

Based on March American Futures—9.50d.

We are,
Yours faithfully,
WOLSTENHOLME & HOLLAND.

LINT CHART :

(Description of Plate XVIII.)

A photograph of a lint chart of Gold Coast and Togoland cottons is here reproduced. From this the superior long silky lint of natural hybrid No. 28 is noticeable, also the inferior and coloured staples of the varieties which are being dropped (Nos. 5, 6 and 7). The varieties represented in the photograph (Nos. 1 to 7) are as follows :—

No. 1. Natural Hybrid No. 28 Kpedshu Br. Togoland female parent (*G. peruvianum*, male parent unknown).
No. 2. " Soncho " (*G. peruvianum*) Br. Togoland.
No. 3. " Kadeanyigba " (*G. hirsutum-punctatum* ?) Br. Togoland.
No. 4. " Gummanli " (*G. punctatum* Sch. & Thon. var. nigerica) Northern Territories, Gold Coast.
No. 5. " Kpalagunda " (*G. arboreum* Linn) Northern Territories, Gold Coast.
No. 6. " Sagai " (*G. punctatum* Sch. & Thon form) Northern Territories, Gold Coast.
No. 7. " Deti-Chien " (*G. mexicanum-hirsutum* ?) Br. Togoland.

(Thanks are due to the Director of the Royal Botanic Gardens, Kew, and Sir George Watt for providing specific identity of some of these cottons.)

PLATE XVIII.

PAPER No. XIX.

RECENT WORK IN THE EAST ON THE RELATIONS BETWEEN STOCK AND SCION IN BUDDING AND GRAFTING.

By G. G. AUCHINLECK, M.Sc., F.I.C.,
Deputy Director of Agriculture.

During a visit in 1926 to Sumatra, Java and Malaya, there were several opportunities of noting the great strides made by the Dutch and English in their knowledge of the technique of budding and grafting. These processes are used on a large scale for propagating selected strains of Hevea and Cinchona, and in the course of this work a great deal of information has been gained on the question of the relation between stock and scion.

In this article, free use is made of the information willingly given to the writer, and special thanks are due to Major Gough, of Kadjang Estate, Malaya, Dr. P. J. S. Cramer of the Department of Agriculture, Java, Mr. Grantham of Boenoet Estate, Sumatra, and Dr. Kerbosch of the Government Cinchona (Quinine) Plantations at Tjinjiroean, Java.

The Relation in General between Stock and Scion.

When two different strains of a plant are united by budding or grafting, it is taken for granted that the characters of each are carried on unchanged in the composite individual that results. The characters for which the stock has been chosen, such as vigour and resistance to drought or to disease, are assumed to be uninfluenced by the fact that a trunk and branches of quite different habits have been imposed upon the root-system. Similarly, the peculiarities for which the scion has been selected are assumed to be carried on unchanged, in much the same way as a cutting transmits the characters of the tree from which it is taken.

The union between stock and scion is very close, so close that, after a few years, it is practically impossible to detect any external evidence of the junction. The composite plant not only looks like one individual, but in ordinary matters of growth and nutrition it behaves like a single unit : the roots absorb a sufficiency of nourishment from the soil, the leaves extract the wanted quota of carbon from the air, and proportioned, symmetrical, balanced life and growth proceed.

Yet it is clear that the fusing of the two individualities cannot be complete. Certain characters of stock and scion remain distinct and different, and it is precisely this peculiarity which makes the process of budding or grafting valuable to us. The sweet fruits of the selected orange-scion do not become acid because they are borne on the stem and roots of a sour-orange stock. The small, delicately flavoured berries of Arabian coffee are not altered because the stem and roots are of the coarse and hardy Liberian species. The selected scion-stem of Hevea rubber retains its powers of yielding large quantities of latex, although it is mounted on the roots and stem of a coarse, unproductive stock.

So we learn that some characters and powers are altered by budding or grafting, while others remain unchanged. In general, the composite plant is a homogeneous unit, but in certain respects it has a dual individuality, two different degrees of intensity of a character existing unmingled in the same individual. An example of a character remaining distinct in the stock and scion is the occurrence of so-called "graft-hybrids," where a branch is produced which bears flowers of two colours, the origin of the branch being a vegetative bud springing from the line of junction between stock and scion : the tissue of the branch is apparently organically homogeneous, but really consists of united, interwoven tongues of tissues from two different sources ; the tissue from the stock bearing one colour of flower and the scion-tissue bearing the other.

Interaction between Stock and Scion in Hevea Rubber.

By the act of budding, both the stock and the scion sustain a severe shock. Longitudinal growth of the stock is suddenly stopped by the decapitation of the young stem, and for some time afterwards there is a compensatory increase in the rate of circumferential growth. The case of the scion is exactly the oppposite, as the young bud suddenly finds itself driven by the full force of an older, powerful root-system.

In the case of Hevea rubber, four effects of practical importance result from this. The growth of the scion-stem to maturity is much more rapid and the tree becomes tappable at a much earlier age. The stem does not taper, as in normal unbudded rubber, but is of practically the same diameter from the point of junction up to the first branches, with the result that tapping may be carried out at any height and precisely the same amount of latex be obtained. The scion-bark is much smoother and harder than that of unbudded rubber, with the result that a clean, straight tapping-cut with firm edges can be made.

The case of the stock is otherwise. Circumferential growth is rapid, so that the bark becomes soft and corky and much rougher than that of unbudded rubber. In extreme cases, where the disproportion between the ages of the stock and scion is too great or where union has been tardy, the diameter of the stock may be so much greater than that of the scion that an unsightly tree with a permanent weakness at the budding-junction may result.

There is some evidence that the degree of rapidity and completeness of the union of stock and scion does not depend only on the relative ages of the two. In the earlier stages of the work of establishing plantations of budded rubber, very little attention was paid to the characters of the stock: it was assumed that seedlings from unselected trees would suffice as stocks for the delicate, high-yielding strains selected as scions. Experience showed, however, that some strains of scion seemed to possess the power of uniting rapidly and firmly, quite independently of the type of stock upon which they were budded, and that similarly some stocks seemed to unite well and quickly with any strain of scion. These observations point to the necessity for giving a good deal of attention to the choice of the stock, as well as to the selection of scion.

In the case of Hevea rubber, the latex-canal system of stock and scion remain distinct even when union has been so complete that the line of junction is barely detectable externally. In one set of trials, in which a wild type of Hevea with bright, sulphur-coloured latex free of caoutchouc was used as stock and a rubber-yielding strain with normal white latex was scion, no intermingling of the two types of latex-canal took place. Tapping of the scion could be carried right up to the line of junction of the two barks without any yellow latex appearing. Apparently a severed latex-canal becomes sealed at the end which has been cut and does not anastomose with any other canal which may come into contact with it, nor does it continue to grow and penetrate into the tissue on the other side of the cut.

This character is utilised in the treatment of 'Brown Bast', a disease which attacks the tapping-area and stops the flow of latex. It has been found that the diseased area can be permanently and effectively isolated by making an incision, without removing any tissue whatever, around it. The severed canals never unite across the incision, although the cut heals, and there is no transfer of the disease from the isolated area. Presumably the disease normally spreads through the medium of the latex-canals.

An analogous case was noted some years ago in the case of cacao in the West Indies. Alligator cacao (*Theobroma pentagona*) was budded on a Forastero type, and the stem of the scion was later attacked by a fungoid disease to which the Forastero stock was practically immune. The disease stopped at the line of junction of stock and scion, and eventually the scion was killed while the stock produced basal shoots and survived.

Constancy of Habit of the Scion.

In all cases noted in the East, the general manner of branching and the shape of the head were transmitted unchanged from the bud-mother to the scion-progeny. The fact is well known in the case of Hevea rubber, and there are indications that definite practical use will be made of the information, notably where a select high-yielding strain has some defect in its manner of

branching. A case in point is the tendency of some strains to produce a double trunk, the main trunk dividing into two at a distance of 8 or 10 feet from the ground. One of these trunks almost invariably atrophies and breaks off, and strains possessing this undesirable peculiarity will either be discarded or will be provided with a desirable branching-system by budding from a third strain chosen for the purpose.

A remarkable example of transmission of habit of branching from bud-mother to scion has come to light within recent years. In the case of most trees and shrubs the distinction between main branches and horizontal ones is not very marked. In the mango for example branches are found growing at all angles to the normal. But in coffee and kapok the distinction is very marked between the vertical stem and the horizontal laterals, and in cacao the habit of the tree is quite different from that of the vertically growing basal shoot or " sucker " with its distant whorls of three or five horizontal laterals.

In the case of these three plants, the habit of the budded progeny depends upon whether the bud has been drawn from a vertical stem or a horizontal lateral. Buds from the vertically growing stem give rise to scions of similar habit to the bud-parent. On the other hand, buds drawn from a horizontal lateral give rise to prostrate types, and many examples are extant of prostrate types of budded coffee and kapok which have originated in this manner. It seems clear that wherever a very marked differentiation exists between the manner of growth of the stem and that of the lateral the habit of each is transmitted unchanged to the bud-progeny.

Disappearance of Epidermal Prickles of Kapok.

The immense silk-cotton (kapok) trees which are found in West Africa and the West Indies have their stems studded thickly with prickles. These are true prickles, like those of the rose, being purely epidermal and not originating, as spines do, from the wood of the trunk. As the trunk ages and its bark roughens, the prickles are shed, so that they are found only on the relatively younger stems and branches.

The variety of kapok which occurs in Ceylon, Malaya and the Netherlands East Indies is slender-stemmed and never attains great bulk. Botanically it is regarded as identical with the West African type, but in size and in quality of lint the two are very distinct. The Eastern type, too, is without prickles.

It some budding experiments at Buitenzorg, Java, the Java type of kapok was used as stock and the Western type as scion. In each case, the resulting plants were free of prickles : in other words the stems of the scions resembled those of the smooth-barked Eastern type and not those of their bud-mothers. The explanation, probably correct, put forward of this unexpected result is that the scion overleaps the juvenile, prickly stage because it is mounted

on a vigorous, established root-system. It springs at once to maturity and does not pass through the preliminary stage of youth and pricklyness. The phenomenon is therefore a secondary one : there is no question of intermingling of tissues.

Extending the Range of Cinchona by Budding.

Practically all of the cinchona (quinine) plantations of Java use budding as the normal means of propagating their trees. The robust *Cinchona succirubra* is used as the stock and select high-yielding strains of *Cinchona Ledgeriana* as scions. The plants need very special conditions of moisture, elevation, temperature and soil in which to grow, and any wide departure from these conditions retards the development of the tree. Too low an elevation is stated to result in diminution of the percentage of alkaloid in the bark.

The normal profitable range of *Cinchona Ledgeriana*, when grown on its own roots, is 4,500 to 5,000 feet above sea-level, but the range of the hardier *succirubra* is 3,500 to 6,000. The composite plant built up by budding *Ledgeriana* on *succirubra* is stated to have the same range (3,500 to 6,000 feet) as *succirubra*, and the plantation-industry to have extended accordingly.

It seems to be accepted as fairly certain that change of elevation, quite apart from concomitant alterations of temperature and moisture, do affect the growth of cinchona and the percentage of alkaloid in the bark. If this be correct, it must be ascribed to variation of atmospheric pressure, and the influence of the scion had been fundamentally changed by the influence of these variations on the growth and life-functions of the plant. The extension off the elevation of *Ledgeriana* must then be regarded as an unusual and remarkable case of reaction of stock upon scion. In a budded plant, the main body of the tree is the delicate *Ledgeriana* and only the root-system is *succirubra*, so that one would not expect any marked change in power of resistance to altered pressure, to be brought about by budding, unless the nature of the scion had been fundamentally changed by the influence of the stock. More explicit evidence is needed of the true effect of change of elevation apart from the masking effects of altered temperature and soil conditions.

Programme of Work needed in the Gold Coast.

This paper has been written in order to direct attention to difficulties which may arise when budding and grafting receive attention in the Gold Coast. In this Colony, no evidence has been gathered on the uses and results of budding, but it seems clear that very marked increases in yield could be brought about in the cases of several local crops if a systematic programme of selection, budding and grafting were adopted.

Some preliminary work of selection has been accomplished by recording the yields of individual trees of cacao and cola on some of the Experiment Stations, but the further step of using the best of these trees as scions, and of spreading them over the country, has been neglected. There is also the possibility that coffee, kapok and the citrus group may become of commercial importance in future years, and, in that case, a study of the effects and uses of budding and grafting will be imperative. Work of this kind has been too long neglected in the Gold Coast, and should be set in hand as early as possible.

PAPER No. XX.

SCHOOL GARDENING.

By T. HUNTER,

Superintendent, Training Centre, Kumasi.

The School Garden movement was in existence during early mission days but no records are available. Classes in Agriculture for School Teachers and Students under training was arranged for in 1902 at the various Agricultural Stations, but no candidates were available until 1904, since when these classes have been continued up to date.

Teachers' Training Classes.

The course is divided into two sections which are taken during school vacations in January and July, each course occupying three weeks. Lectures and demonstrations are given daily for about one to one and a half hours, the remainder of the day being spent in performing practical work in the field, under the supervision of the officer-in-charge of the Agricultural Station where the course takes place.

The training, briefly stated, embraces the following :—The plant and its requirements of air, soil and water ; structure and functions of various plant organs, seed, seed dispersal, etc. Soils, formation, classification—chemical and physical properties. Cultural operations, digging, hoeing, manuring, mulching, draining, study of soils and climatic conditions suited to various crops, insect pests, and fungoid diseases. Formation and management of School Garden. Practical work—uses of various tools required for the School Garden. Nursery work—methods of propagating plants, potting, transplanting and watering. Soil tillage—lining, holing, planting, and various cultural operations ; harvesting and preparation of various crops. Practical treatment of fungoid diseases and insect pests.

No figures are available as to the actual number of teachers who have taken these courses, but 916 certificates have been awarded resulting from the examinations held at the end of each course between the period 1904-1925.

Results.

It has frequently been observed that the students deriving greatest benefits, are those who have received tuition in Training Colleges where Nature Study has received special attention. This tends to illustrate the need for a closer connection beween Nature Study and practical work in the garden which has not received the attention it deserves.

The results of the above courses have been fairly satisfactory when it is considered that the courses are very short, and arranged to fit in with the school vacations. These unfortunately, are not the best times of the year when the more important work of an Agricultural Station is carried out, and for a long time it has been recognised that much better results would be obtained if a more extensive system of training could be carried out throughout the whole of the Teachers' training.

When one examines the work done in School Gardens in this country it would appear that, with few exceptions they have not fulfilled their purpose.

This state of affairs is not peculiar to this country, and many more advanced countries have only in recent years paid proper attention to School Gardens.

The writer has been in close touch with many of the School Gardens during the last fifteen years, and is in a position to sympathise with the teachers who have worked under great disadvantages. Many of the teachers have tried to fully understand the work, but lack of organisation and necessary supervision have been largely responsible for the indifferent results.

A teacher in this country is naturally restricted in his efficiency. He is unable to apply his knowledge to unusual conditions, or prepare for anticipatory action where initiative is required.

Patience and frequently repeated instructions are essential to get him to understand what exactly is required, and this is only possible where frequent inspections can take place.

Reasons for Partial Failure.

The Education and Agricultural Departments have worked in close co-operation, but when it is realised that until the last few years, at most one European Agricultural Officer was available in each Province, and the inspectorate staff of the Education Department only allowed for occasional visits of inspection to schools, the indifferent results under such conditions can be readily understood ; further in many cases owing to frequent changes of teachers, there has been a lack of continuity in carrying out plans thereby limiting the possibility of success.

During the period 1915 to 1920 the writer paid quarterly visits to the five gardens in Kumasi in addition to many others in Ashanti during tours of itinerant work. A Circular, together with type-plan, was drawn up outlining what was required in a garden, and many teachers showed quite good results in following this plan.

One teacher in particular did extremely well, but unfortunately was transferred to another sphere of work just as the results began to show themselves, and the subsequent teachers were not so keen, therefore the good work originally done gradually deteriorated until the Garden was eventually abandoned.

As a general rule when inspecting School Gardens, one cannot fail to observe the outlook of drudgery that must appear at the back of the pupils' mind during garden work. The interesting part of the work, training the pupils powers of observation—the wonders of nature study and plant life, are usually neglected and what lessons are actually conveyed to the pupil leave him with at the most but a vague knowledge of such.

The Teachers' Function.

The connection between Nature Study and School Garden work is too little understood; the many useful lessons which might be carried from the class-room to a garden and, *vice versa*, are rarely attempted.

The value of such work depends on the teachers, and although the practical work—so far as agriculture is concerned—is often well carried out, few teachers take sufficient close interest in the work they have in hand. Endeavours should be made to make the pupil realise that the plant he cultivates is a living organism, which requires attention regarding feeding and environment, as he himself does, and that both require food and air to lead an organised existence; further, how dependent we are on the green plant, for all our necessaries of life.

An example of a teacher's inability to apply himself to lessons in a practical manner was recently experienced by the writer. A teacher, about to give a lesson on fungoid diseases, wrote to the nearest Agricultural Station and asked for specimens for demonstrating purposes. In this particular case a large rubber plantation is almost opposite the school, a large cacao farm within 200 yards, and many food farms near by, which would have provided all the material required.

A visit to any of the farms in question would have been of far greater value than an attempt to demonstrate fungoid diseases in a class-room. This shows lack of thought on the teacher's part which frequent inspection and guidance should remedy.

School Gardens to be effective, must be definitely organised, the teacher's training improved, and work frequently inspected to obtain the best results.

One frequently sees plans for pupils' training in School Garden work, but no thought is given to the teachers' training, which is the first essential to sucess.

In an agricultural country like this the teachers' training should be based on agriculture, and do this successfully it must be carried on throughout the college career.

Work at Wesley College.

During the past year a scheme of work has been laid down at Wesley College, Kumasi, which indicates the lines on which teachers' training can be carried out. Throughout the four years'

training, four hours per week are alloted to practical work in agriculture carried on in the School Garden. A plan has been drawn up which is worked as follows :—

A. First Year Students are mostly engaged in keeping the school surroundings neat and tidy. This enables them to become acquainted with their surroundings, and carry on preliminary studies.

B. Second Year Students take up cultivation in groups in the agricultural plots.

C. Third and Fourth Year Students have individual plots from which one can form a good idea of the interest shown by the individual, and allow for a competitive spirit amongst students.

D. Useful diaries are kept by students, and they are encouraged to make entries respecting work done, and to record general observations.

General food crops such as cassava, corn, coco-yams, yams, onions, okroes, are grown. A fruit-orchard and nursery have been formed. All crops are used in the college kitchen. Each student is credited with the value of crops produced from his plot, and prizes are awarded each term to the most successful students. A plan of the lay-out of the garden is given in Plate XIX. The system of rotation used is as follows :—

SUMMARY OF ROTATION AND CONTROLS.

Year.	PLOTS							
	A		B		C		D	
	Rotation.	Control.	Rotation.	Control.	Rotation.	Control.	Rotation.	Control.
1926.	Corn.	Corn.	Yam.	Yam	Tomatoes and Garden eggs.	Tomatoes and Garden eggs.	Ground nut.	Ground nut.
1927.	Yam.	Corn.	Tomatoes and Garden eggs.	Yam.	Ground nut.	Tomatoes and Garden eggs.	Corn.	Ground nut.
1928.	Tomatoes and Garden eggs.	Corn.	Ground nut.	Yam.	Corn.	Tomatoes and Garden eggs.	Yam.	Ground nut.
1929.	Ground nut.	Corn.	Corn.	Yam.	Yam.	Tomatoes and Garden eggs.	Tomatoes and Garden eggs.	Ground nut.

N.B.—1. Same crops to be grown on the Control Areas during the four years as shown in the Summary.

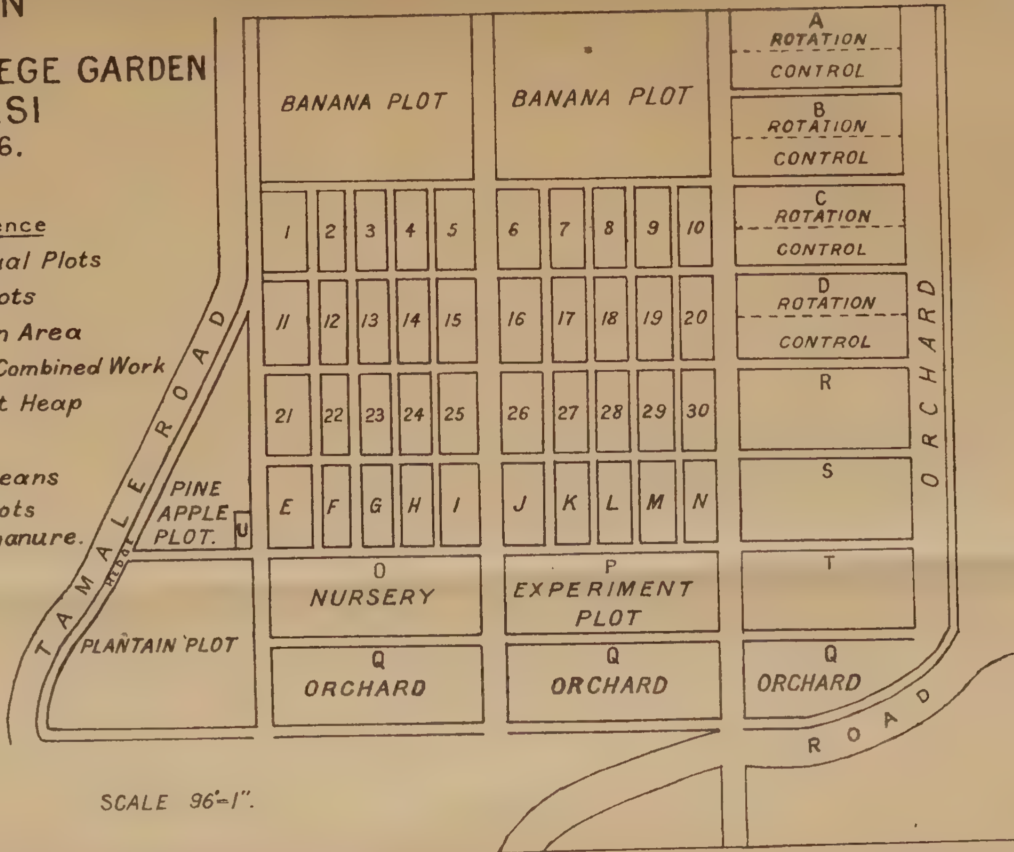
PLATE XIX.

PLAN OF WESLEY COLLEGE GARDEN KUMASI 1926.

Reference

1-30	Individual Plots
E-N	Dual Plots
A-D	Rotation Area
R-T	Plots for Combined Work
U	Compost Heap

As crops mature beans are grown on all plots to dig in as green manure.



SCALE 96'=1".

Reproduced at Survey H.Q. Accra, 1927.

This arrangement enables the students to form a good idea of what is required and how to manage a School Garden; further, having worked continously for four years, it gives the students an opportunity to see results and the varying conditions which exist, therefore he learns where anticipatory action is necessary.

Regular visits to Kumasi Agricultural Station, and local farms, are arranged for the purpose of general observations and study of agriculture.

Perennial Crops Inadvisable.

Although intensive cultivation of food crops is of most value and permanent crops are not really subjects for School Gardens yet each teacher should have a knowledge of the cultivation and preparation of our most important crops, diseases and pests, and how to control them. This is where excursions to Agricultural Stations and local farms are of value.

The general principles outlined for teacher's training should be carried out in practice in the ordinary School Garden, and the pupils encouraged thereby to take a more intelligent interest in the work undertaken.

In every school the children should be taught how much better it is to have one's surroundings neatly planted, and how valuable shade trees are as protection from the sun. Small nurseries should be maintained at all schools to raise plants, not only for the school surroundings, but also for the pupils to take home; the latter affording an excellent opportunity for developing individual taste and serving as a demonstration to others who have not had the opportunity of attending school.

Teachers while in the garden should bring to the pupils' mind some lesson apart from the actual work in hand. A few moments spent observing the germination of seeds etc., measuring and recording the growth of plants since a previous visit, and similar observations would encourage pupils to realise that their labours are not in vain, or devoid of interest.

Suggestions.

A teacher, especially in country districts, should be encouraged to do something to gain the confidence, not only of the pupils, but also the people with whom he comes in contact. He should be able to impart useful information to the farmers around him and help to advise and guide them in matters which they do not understand.

Health Weeks are now an annual feature of our large towns. Why not a health week on our cacao farms? The subject affords plenty of scope for action on the part of teachers and pupils.

To carry into effect the scheme outlined above we must have efficiently organised supervision, with a definite object in view. An Organiser of School Gardens is necessary, and a proportion of the teachers should specialise in Nature Study and School Garden work. Wood and metal work in the larger schools have special Instructors. Surely Nature Study and School Gardens are worthy of similar attention.

Such teachers must have sufficient time to prepare lessons in order to make them of utmost value. From these teachers it would be possible to select inspectors who should be trained to travel round organising the work for smaller School Gardens so that all might be worked according to a uniform system. This latter would of course have to be arranged to suit the localities, rainfall, periods of drought etc.

PAPER No. XXI.

RAINFALL OF THE GOLD COAST FOR THE YEARS 1925–1926.

(RECORDS COMPILED IN HEAD OFFICE BY J. M. ADAMS).

Past records of rainfall of the Gold Coast for 57 stations were summarized up to the end of 1924 in Bulletin No. 2 of the Department of Agriculture. The following stations, records of which were given in that Bulletin, had been discontinued before 1925 :-

Ada, Birimsu, Bunsu, Cape Coast, Gambaga, Goaso, Labolabo, Navrongo, Nkwatia, Obuasi, Winneba.

After 1925 the following stations were discontinued :—
Ayinasu, Adebrem.

On the other hand, the following new stations provided records in 1925 and 1926 :—

1925. *Achimota, Mpennasa.*
1926. *Adeja, Agona, Angu, Asromaso, Atuabo, Dentin, Effiduase, Ejisu, Essuasu, Inchaban, Kodia Kese, Mampong (Ash.), Mpirim, Nkawkaw, Nsawam, Tafo, Tikrom.*

There are therefore records from 48 stations in 1925 and from 63 stations in 1926.

The Department of Agriculture is indebted, for the records from the ten Ashanti stations opened in 1926, to Capt. C. Wilson Brown, the Senior Hydraulic Engineer, Public Works Department. Several of the stations are in an area from which there has been a dearth of information in the past, and the figures will therefore be of unusual value.

Check Readings.

In two cases in 1926, records were obtained from two different gauges at the same station. An opportunity was therefore afforded for the first time of judging the accuracy with which records are taken.

Results were as follows :—

	Sekondi.		Tarkwa.	
	Railway.	Medical.	Railway.	Agriculture.
January ..	.30	.37	—	—
February ..	.71	.90	—	—
March	2.20	2.21	4.42	4.82
April	1.03	1.12	3.92	3.35
May	5.36	5.98	7.95	7.09
June	9.68	10.13	21.49	19.68
July	.46	.40	1.60	1.77
August	.34	.24	2.02	2.12
September ..	3.43	3.55	5.44	6.09
October	2.73	2.76	10.53	10.25
November ..	4.13	4.24	10.06	11.23
December ..	.95	1.08	4.51	5.40
Total ..	31.32	32.98	71.94	71.80

In the case of Sekondi the largest variation for one month was .62 of an inch in May. In June the Railway reading for Tarkwa was 1.81 higher than that of the Department of Agriculture. In each case the year's totals were practically the same.

Rainfall Tables.

Tables II and III, at the end of this paper, give the monthly rainfall at each station for 1925 and 1926. These tables also give the highest and lowest rainfalls recorded in previous years at each stations.

Unusual rainfalls in 1926 were those at Accra (10.84) and Labadi (10.78). These are lower than have ever been previously recorded in any part of the country.

Degrees of Wetness.

In attempting to form some judgment as to the wetness or dryness of a particular place, we are met by the difficulty that a mere statement of the total amount of rainfall per year, or even per month, does not suffice. The distribution of the annual rainfall is clearly an important factor. Fifty inches well distributed over the year is more beneficial than seventy-five falling in certain months and drought for the remainder of the year.

In Table I, an attempt is made to combine the two factors. The number of inches of rainfall for the year is multiplied by the number of days on which rain fell. In order to reduce the product

to convenient dimensions, the last two whole numbers are discarded in each case: thus a rainfall of 80 inches falling on 120 days in the year gives a product 80 x 120 = 9,600, and, discarding the last two figures, 96 is taken as the degree of wetness.

All that can be said at present is that this figure appears to give a better notion of the comparative wetness of a station than does the figure for total annual rainfall or for number of days on which rain fell when either is separately considered.

TABLE I.

DEGREES OF WETNESS.

Inches of rain x number of days of rain.

1925.		1926.
—	160	Axim.
—	125	Tarkwa.
Begoro	110	—
—	103	Abompasu.
Asamankese	101	—
—	98	Kibi, *Kodia Kese.*
Abompasu	95	—
Tarkwa	90	*Mpirim.*
—	89	*Agona.*
Kumasi	87	—
Siwum	85	—
—	84	Siwum.
—	83	Juaso.
Kibi, Juaso	82	Kintampo.
Kintampo	81	—
Axim	80	Anyinam.
Ayinasu	79	—
—	78	Dunkwa, Kumasi.
Hemang	76	Half Assini, Seysie.
—	75	*Ejisu.*
Dunkwa	74	—
Oda, Mpraeso	73	—
Aburi, Kete-Krachi	71	Wiawso.
—	69	Asamankese.
—	68	Mpraeso.
—	67	Begoro.
Ejura	63	—
Asuansi	61	*Mampong* (Ash.)
Seysie, Ho, Wiawso	60	—
—	58	Oda.
Mansu, Wa	54	*Tafo*, Koforidua.
—	53	*Nkawkaw*, Asuansi.
Sunyani	52	*Tikrom.*
Bekwai, *Adebrem*	51	Wenchi, Mansu, Mpennasa.
Wenchi	50	Ho, Ejura.
Kpedshu	49	*Esuasu*, Aburi.
Mpennasa, Yendi, Tamale	48	*Nsawam.*
Adjua, Salaga, Koforidua	47	Kete Krachi.
Half-Assini	43	Adjua.
—	42	Bekwai, Hemang.
—	41	Tamale.
Sekondi	40	*Angu*, Sunyani.
—	38	Salaga.
Odumase	36	—
Anyinam	35	Sekondi.
—	31	Odumase.
Zuarungu	29	—
Peki Blengo	28	Kpedshu.
—	27	Peki Blengo.
—	26	Yendi.
Abra, Accra	24	Akuse.
Akuse	23	Zuarungu.
Saltpond	22	—
—	18	*Atuabo*, Abra, Wa.
Keta	16	—
—	12	Saltpond.
Labadi	11	—
—	10	Keta.
—	8	*Achimota.*
—	6	Accra.
—	3	Labadi.

N.B.—Names of stations for which only one year's record is available are printed in italics. Adeja, Asromaso, Effiduase and Inchaban do not appear as these stations were opened only in middle of 1926.

TABLE II.

Summary of Rainfall in inches for all Stations in the Gold Coast for the year 1925.

Month.	1 Asamankese	2 Siwum.	3 Pegoro.	4 Dunkwa.	5 Ayinasu.	6 Kibi.	7 Axim.	8 Kumasi.	9 Yendi.	10 Salaga.	11 Juaso.	12 Abompsɑu.	13 Ejura.	14 Kintampo.	15 Oda.	1 Half-Assini.
January	.00	.00	.00	.00	.00	0.8	0.45	.00	.00	.00	.00	.00	.00	.00	.00	.00
February	1.85	0.68	1.98	0.70	0.39	3.76	0.55	1.10	.00	0.56	.00	1.99	3.28	1.30	1.61	0.20
March	8.57	6.07	10.43	9.60	7.06	10.42	12.25	8.79	3.01	5.50	6.57	11.28	6.57	4.19	6.50	8.65
April	10.48	8.49	6.17	7.80	6.10	8.69	6.06	4.67	3.11	1.60	3.03	4.61	2.66	1.67	11.67	6.45
May	9.37	11.07	7.74	10.95	7.03	9.47	5.75	8.09	6.45	7.06	5.58	7.91	8.94	7.43	6.90	9.57
June	14.48	14.87	10.87	20.44	13.02	10.45	26.26	9.52	6.87	8.40	12.43	11.86	3.24	6.61	9.41	24.70
July	3.94	14.06	3.76	7.56	9.53	4.34	11.63	7.25	3.59	7.84	12.33	3.23	6.38	10.14	7.24	5.90
August	6.24	4.57	10.67	5.06	5.65	3.15	1.37	6.48	10.30	9.65	4.27	8.09	5.36	6.35	6.13	.00
September	5.34	5.25	5.87	5.27	7.41	3.01	2.36	4.66	20.05	10.20	4.27	6.14	6.28	9.63	5.38	0.86
October	4.70	3.14	8.85	0.67	5.77	5.31	0.12	8.88	6.96	9.80	8.58	1.19	11.43	10.23	2.89	0.70
November	4.79	4.95	5.76	3.59	4.43	9.62	0.69	7.56	6.78	5.22	7.26	5.26	8.32	4.92	3.95	3.07
December	7.71	0.47	0.76	0.55	3.64	1.62	1.92	0.24	.00	.00	0.99	3.62	0.03	.00	.00	1.53
Total	77.47	73.62	72.86	72.19	70.03	69.92	69.41	67.24	67.12	65.83	65.31	65.18	62.49	62.47	61.78	61.63
No. of Rainy Days (.01 inch or more)	130	115	151	103	113	118	116	130	72	72	125	146	101	129	118	71
Highest previous rainfall	—	—	-	77.91	68.60	79.90	109.65	70.40	—	64.52	75.19	—	80.75	100.58	83.75	—
Lowest previous rainfall	—	—	—	45.55	41.95	45.77	47.64	40.07	—	37.79	53.42	—	47.45	48.87	43.61	—

TABLE II.—*continued.*

1925.—*continued.*

Month.	17 Mpraeso.	18 Wenchi.	19 Hemang.	20 Wa	21 Mpennasa.	22 Mansu.	23 Tarkwa.	24 Seysie. (Butre).	25 Aburi.	Wiaso.	27 Anyinam.	28 Bekwai.	29 Adjua.	30 Kete Kratchi.	31 Peki Blengo.	32 Asuansi.
January	.00	.00	.00	.00	1.63	.00	.00	2.45	.00	.00	.00	.00	.00	.00	.00	0.18
February	0.42	1.29	0.04	.00	1.85	0.80	1.19	1.25	2.68	0.32	.00	1.00	1.32	1.04	2.80	0.35
March	7.87	1.94	6.73	1.82	3.21	6.43	8.32	3.88	5.38	6.66	.00	8.60	3.40	4.05	2.25	4.18
April	3.74	7.77	7.15	1.07	4.15	4.85	4.67	2.18	6.05	6.93	6.97	2.00	2.70	3.54	7.06	2.41
May	9.97	4.47	6.76	11.02	6.18	4.35	6.80	0.86	8.23	8.61	7.00	7.00	3.43	5.16	8.12	6.74
June	7.61	8.33	15.58	4.54	23.90	20.80	16.04	24.38	14.16	11.94	11.31	11.75	25.08	4.82	6.00	15.40
July	2.43	5.43	5.74	5.43	10.55	7.47	7.79	8.06	4.34	8.50	5.21	3.75	12.26	5.32	2.72	5.39
August	5.78	388	1.89	11.54	1.49	1.17	2.26	1.16	2.65	2.87	2.69	6.75	1.22	11.47	5.31	3.04
September	7.25	11.01	9.36	17.68	1.91	4.21	4.31	2.73	3.35	5.22	6.32	4.50	2.19	8.41	5.14	5.64
October	10.00	12.29	1.57	4.81	0.27	2.86	1.66	0.27	2.74	1.33	11.60	3.50	2.09	5.53	3.38	1.73
November	4.65	3.94	5.50	2.45	3.18	2.67	4.87	0.75	4.71	3.83	4.68	6.25	0.31	4.10	8.26	0.99
December	1.44	0.60	0.04	.00	1.95	3.77	1.20	1.09	2.93	0.87	0.39	0.50	1.50	.00	1.16	5.99
Total	61.16	60.95	60.36	60.36	60.27	59.38	59.11	58.96	57.22	57.08	56.17	55.60	55.59	54.13	52.20	52.04
No. of Rainy Days (.01 inch or more)	120	83	126	89	80	91	153	102	124	105	63	91	85	132	53	118
Highest previous rainfall	85.26	—	85.86	50.71	—	83.70	95.03	—	73.16	—	95.07	104.90	49.93	60.41	68.46	74.17
Lowest previous rainfall	57.55	—	58.64	30.65	—	54.46	48.22	—	32.09	—	46.27	53.64	36.81	43.61	30.33	35.62

TABLE II.—*continued.*

1925.—*continued.*

Month.	33 Kpedshu.	34 Koforidua.	35 Sunyani.	36 Adebrem.	37 Ho.	38 Odumase.	39 Tamale.	40 Sekondi.	41 Zuarungu.	42 Accra.	43 Saltpond.	44 Labadi.	45 Keta.	46 Abra.	47 Akuse.	48 Achimota.
January	0.23	.00	.00	.00	0.03	.00	.00	.00	.00	.00	1.07	0.62	.00	0.50	0.35	—
February	3.94	1.08	0.11	0.71	0.72	.00	.00	0.30	0.55	1.87	0.90	0.90	.00	0.16	2.10	—
March	5.91	4.41	5.82	4.66	7.57	.00	1.77	2.83	1.44	4.43	6.26	6.65	4.22	4.03	2.75	3.36
April	3.97	8.29	2.12	5.45	8.16	4.25	2.12	3.58	1.53	3.58	1.76	2.28	1.83	2.02	5.19	2.97
May	4.42	4.88	6.74	5.41	7.01	2.93	3.99	6.42	3.11	1.21	3.48	0.90	7.49	5.50	5.04	1.30
June	9.48	13.08	10.40	16.85	5.28	4.50	5.94	19.34	8.39	23.96	17.63	23.32	17.56	15.33	5.06	11.62
July	3.69	2.49	10.06	9.51	3.14	4.66	2.74	5.78	3.82	0.89	3.06	.00	3.95	2.75	1.66	2.30
August	6.21	2.02	4.56	2.48	5.06	3.56	5.71	1.27	8.18	1.64	0.77	1.60	1.03	0.58	2.92	0.41
September	5.72	4.11	4.47	2.60	4.61	6.89	13.28	2.35	7.30	0.72	1.01	0.40	0.30	1.98	3.65	1.86
October	4.31	8.48	6.57	0.30	3.13	10.44	7.57	0.48	5.05	0.02	0.09	.00	.00	0.10	1.11	.00
November	2.34	1.82	4.04	1.12	3.27	9.36	2.65	0.34	0.45	0.08	0.04	.00	.00	0.01	1.14	.00
December	1.73	1.12	.00	1.34	1.79	.00	.00	1.02	.00	0.09	1.02	0.20	.00	1.22	1.62	0.27
Total	51.95	51.78	54.89	50.43	49.77	46.59	45.77	43.71	39.82	38.49	38.09	36.87	36.38	34.18	32.59	24.09*
No. of Rainy Days (10 inch or more)	95	90	103	101	120	77	104	91	73	63	58	31	43	63	70	57
Highest previous rainfall	—	—	69.47	—	—	—	61.77	57.76	51.62	44.20	43.80	—	51.44	—	58.98	—
Lowest previous rainfall	—	—	41.30	—	—	—	32.36	33.80	37.93	15.87	24.38	—	13.88	—	35.14	—

*Figures for 10 months only.

TABLE III.

Summary of Rainfall in inches for all Stations in the Gold Coast for the year 1926.

Month.	1 Half-Assini.	2 Kodia Kese.	3 Axim.	4 Tarkwa.	5 Essuasu.	6 Kibi.	7 Siwum.	8 Anyinam.	9 Kintampo.	10 Abompasu.	11 Agona.	12 Mpirim.	13 Juaso.	14 Ejisu.	15 Dunkwa.	16 Tafo.
January	1.76	0.21	.99	.83	1.27	.86	.00	.00	.00	.26	0.40	0.84	.85	.00	.10	1.18
February	1.81	0.94	2.38	1.51	0.00	.81	4.00	2.40	.00	.52	3.52	3.54	.26	4.49	.74	0.68
March	5.81	5.69	3.26	4.82	6.57	10.03	5.35	6.84	4.51	4.04	3.31	1.67	4.03	3.71	2.77	3.74
April	7.90	9.52	0.81	3.35	3.31	8.03	8.34	7.59	5.89	4.38	6.70	11.86	9.14	8.25	6.73	5.83
May	16.28	8.11	17.97	7.09	14.28	10.39	9.00	8.24	4.68	10.64	5.97	11.08	7.91	8.58	7.33	7.48
June	29.59	17.10	26.58	19.68	19.42	14.17	8.61	8.24	12.26	17.24	17.86	13.58	10.77	10.70	14.15	14.40
July	1.00	4.89	7.26	1.77	1.68	4.80	10.75	7.54	11.94	9.82	5.93	5.23	6.11	4.35	10.85	3.83
August	1.05	1.70	0.79	2.12	1.44	0.18	2.60	0.82	7.55	0.72	3.46	1.74	4.87	1.24	0.46	0.87
September	2.68	19.56	5.94	6.09	13.10	6.54	6.60	10.95	12.65	8.93	6.98	8.06	6.13	10.05	5.74	7.48
October	9.15	10.79	8.60	10.25	7.84	7.74	8.65	8.98	4.15	5.37	6.85	4.49	6.68	7.91	8.34	8.34
November	6.92	2.72	8.90	11.23	3.17	4.96	5.35	4.87	3.68	3.82	4.89	4.50	5.84	4.09	3.22	6.84
December	4.82	4.60	1.48	5.40	1.30	2.31	1.36	2.14	0.52	1.65	1.28	0.55	2.52	1.08	2.08	0.72
Total	88.77	85.83	84.96	74.14	73.38	70.82	70.61	68.61	67.83	67.39	67.15	67.14	65.11	64.45	62.51	61.39
No. of Rainy Days (.01 inch or more)	86	114	189	169	—	139	119	116	121	159	133	135	128	117	125	—
Highest previous rainfall	—	—	109.65	95.03	—	79.90	73.62	95.07	100.58	—	—	—	75.19	—	77.91	—
Lowest previous rainfall	61.63	—	47.64	48.22	—	45.77	—	46.27	48.87	65.18	—	—	53.42	—	45.55	—

TABLE III.—*continued.*

1926.—*continued.*

Month.	17 Mpraeso.	8 Nkawkaw.	19 Mampong (Ashanti).	20 Mansu.	21 Tikrom.	22 Wenchi.	23 Mpennasa.	24 Seysie (Butre).	25 Kumasi.	26 Wiawso.	27 Koforidua.	28 Ho.	29 Ejura.	30 Kete Kratchi.	31 Asamankese.	32 Sunyani.
January	.09	0.00	0.00	2.85	.00	.00	1.73	0.79	0.23	0.14	0.03	1.72	.00	.00	0.97	.00
February	1.21	1.20	1.65	0.53	0.07	0.58	4.48	3.14	1.91	0.03	5.00	1.01	.00	.00	0.87	.00
March	6.60	6.85	2.70	2.79	4.92	3.38	3.20	2.27	4.94	3.55	5.32	3.38	5.23	2.01	5.03	5.09
April	8.48	7.65	9.52	3.84	6.29	7.29	2.68	2.65	7.24	4.46	4.32	8.04	5.27	3.28	4.52	4.57
May	6.08	5.05	12.97	7.09	6.84	10.28	11.95	16.76	9.61	3.37	3.84	7.34	3.39	5.96	5.84	5.54
June	8.04	7.50	9.79	16.55	12.45	13.78	21.30	17.45	11.73	14.17	15.46	10.23	12.89	13.40	9.29	7.61
July	6.57	10.05	4.70	2.25	5.72	3.12	1.79	2.29	4.69	6.10	1.52	4.36	4.95	11.27	3.40	6.37
August	5.10	2.95	0.94	1.40	0.98	2.25	0.44	0.48	2.12	1.93	0.35	1.67	3.25	2.00	1.44	2.00
September	7.29	7.05	9.65	9.09	8.82	11.63	3.02	3.05	2.79	7.23	4.95	6.46	9.39	7.87	5.88	11.89
October	5.51	7.45	4.58	5.85	8.16	4.75	5.10	4.23	5.40	5.00	5.23	4.02	4.78	4.01	6.30	6.36
November	2.49	3.40	3.07	4.60	4.51	0.99	1.85	3.57	4.20	5.60	5.64	2.95	2.79	1.06	5.63	1.02
December	3.48	1.53	0.39	2.65	0.61	0.20	1.42	1.62	2.29	5.29	2.25	0.98	0.17	0.83	2.26	0.50
Total	60.94	60.68	59.96	59.49	59.37	58.25	58.96	58.30	57.15	56.87	53.97	52.16	52.11	51.69	51.43	50.95
No. of Rainy Days (.01 inch or more)	112	—	—	85	—	87	87	130	136	125	100	96	96	91	134	78
Highest previous rainfall	85.26	—	—	83.70	—	60.95	60.27	58.96	70.40	70.44	—	—	80.75	60.41	—	69.47
Lowest previous rainfall	57.55	—	—	54.46	—	—	—	—	40.07	40.14	51.78	49.77	47.45	43.61	77.47	41.30

TABLE III.—*continued.*

1926.—*continued.*

Month.	33 Begoro.	34 Angu.	35 Peki Blengo.	36 Oda.	37 Nsawam.	38 Aburi.	39 Hemang.	40 Bekwai.	41 Yendi.	42 Tamale.	43 Asuansi.	44 Odumase.	45 Salaga.	46 Inchaban.	47 Adjua.	48 Kpedshu.
January	.00	1.45	.00	.00	0.45	0.45	0.30	.00	.00	.00	0.00	.00	.00	.063	.066	0.92
February	0.41	0.61	1.78	0.87	1.23	1.25	2.02	.00	0.03	.00	1.90	0.15	.00	0.89	0.50	0.15
March	5.24	2.66	2.00	6.18	4.39	4.57	6.50	4.25	0.98	1.75	4.84	6.17	2.08	3.98	1.50	3.98
April	6.17	1.76	6.97	4.89	2.63	2.86	7.41	6.50	3.97	0.95	1.34	3.94	3.45	1.78	1.42	7.19
May	8.01	7.04	9.78	7.39	5.71	5.79	.00	7.25	10.46	6.46	7.07	4.34	7.07	5.36	11.20	4.64
June	7.62	16.00	6.42	8.67	15.89	13.28	.00	9.00	3.94	4.56	12.40	7.82	6.54	18.40	13.81	6.23
July	5.57	1.50	11.26	0.48	1.54	2.89	.00	4.00	3.71	9.91	0.79	2.15	7.38	1.70	0.89	1.07
August	1.01	0.15	2.17	0.64	0.30	0.49	0.96	0.85	7.98	10.67	0.94	1.12	7.67	0.45	0.17	1.16
September	6.68	6.28	2.29	6.89	8.17	7.97	6.84	5.70	11.46	8.28	4.01	10.48	6.34	3.25	3.99	2.20
October	4.72	5.98	2.82	5.54	5.48	4.30	8.97	5.47	3.44	1.17	5.00	4.54	2.77	2.22	3.93	2.99
November	3.60	3.18	3.22	6.65	2.32	2.46	9.02	2.34	0.15	0.68	2.28	2.54	.00	2.01	1.52	8.57
December	1.40	2.97	0.78	0.87	0.90	1.44	5.02	0.85	.00	0.27	2.72	0.18	0.12	0.71	1.42	0.97
Total	50.43	49.58	49.49	49.07	49.01	47.75	47.04	46.21	46.12	44.70	43.92	43.43	43.42	41.38	41.01	40.07
No. of Rainy Days (.01 inch or more)	134	80	54	118	—	102	89	91	56	92	122	71	89	—	105	71
Highest previous rainfall	72.86	—	68.46	83.75	—	73.16	85.86	104.90	67.12	61.77	74.17	49.77	64.52	—	49.03	51.95
Lowest previous rainfall	—	—	36.33	43.61	—	32.09	58.64	53.64	—	32.36	35.62	—	37.79	—	36.81	—

TABLE III.—*continued.*

1926—*continued.*

New Stations.

Month.	49 Zuarungu.	50 Akuse.	51 Sekondi.	52 Wa.	53 Keta.	54 Abra.	55 Saltpond.	56 Achimota.	57 Accra.	58 Labadi.	59 Atuabo.	60 Asromaso.	61 Effiduase.	62 Adeja.
January	.00	0.07	0.37	.00	0.13	0.26	0.31	1.28	0.23	0.17	Opened July 1st, 1926.	Records begin on July 1st, 1926.	Records begin on July 1st, 1926.	Opened on October 1st, 1926.
February	.00	0.37	0.90	.00	0.78	1.32	0.36	0.60	0.24	0.21				
March	.00	3.14	2.21	1.27	0.20	2.15	1.62	2.00	0.49	0.70				
April	4.46	3.08	1.12	1.26	3.66	0.77	2.38	1.00	0.32	0.71				
May	4.91	6.92	5.98	5.08	3.46	5.20	2.74	5.10	1.67	2.61				
June	5.00	9.48	10.13	3.10	5.48	4.95	8.73	2.45	1.66	1.77				
July	4.98	0.73	0.40	4.82	1.56	1.10	2.44	1.14	0.75	0.40	1.70	5.00	6.58	
August	10.06	0.41	0.24	7.14	.00	.00	0.03	0.04	.00	.00	.00	1.07	2.04	
September	7.43	2.06	3.55	5.50	6.81	2.16	1.04	3.37	2.40	1.90	6.60	5.41	5.34	
October	0.75	5.57	2.76	0.32	4.16	5.89	2.89	1.80	1.93	1.73	8.65	8.33	4.68	3.40
November	1.00	1.34	4.24	0.59	2.63	2.63	3.96	0.47	0.86	0.58	14.92	2.48	3.62	5.48
December	.00	2.14	1.08	.00	.00	0.76	0.15	1.15	0.29	.00	3.13	0.94	1.77	4.13
Total	38.59	35.31	32.98	29.08	28.87	27.28	26.65	21.00	10.84	10.78	35.00	23.23	24.03	13.01
No. of Rainy Days (.01 inch or more)	61	70	105	62	35	67	44	40	53	27	51	77	73	32
Highest previous rainfall	51.62	58.98	57.76	50.71	51.44	34.18	43.80	24.09	44.20	36.87	—	—	—	—
Lowest previous rainfall .. :	37.93	35.14	33.80	30.65	13.88	—	24.38	—	15.87	—	—	—	—	—

BULLETIN No. 8.

Department of Agriculture,

Gold Coast.

NOTES ON A VISIT TO THE NETHERLANDS INDIES AND THE FEDERATED MALAY STATES.

PART I.—THE PLANTATION OIL-PALM INDUSTRY IN THE EAST.

BY

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FOREWORD.

This Bulletin is based upon the investigation very carefully carried out in the middle of 1926 by Mr. G. G. Auchinleck, Deputy Director of Agriculture, in Federated Malay States, Java and Sumatra of the cultivation of the oil-palm on plantation lines.

While the local industry of the manufacture of palm-oil by crude methods and in a large number of small centres scattered over a large area will never disappear, there is no doubt that the only way to meet the competition of the organised plantation oil-palm industry of the East is to adopt similar methods here.

C. H. KNOWLES,
Director of Agriculture.

ACCRA, 14*th February,* 1927.

CONTENTS.

THE PLANTATION OIL-PALM INDUSTRY IN THE EAST.

I.—INTRODUCTORY.

The material for this report was drawn from notes made during a visit of three months' duration to the Federated Malay States, Java and Sumatra in 1926. The primary object of this visit was the study, on behalf of the Government of the Gold Coast, of the oil-palm industry which is being founded by the Dutch in the East Indies and, to a less extent, by the English in the Malay Peninsula.

The transfer of the oil-palm from its original habitat in West Africa to the East Indies and the conversion of the industry from an irregular and usually wasteful system of collection and preparation into an organised and capitalised enterprise has been attended by a good many difficulties. Methods of cultivation have had to be worked out and machinery has had to be invented, and there have been loss and delay as parts of the price paid for experience. This report therefore cannot claim to be a complete treatise on the cultivation of the oil-palm, and it is at least doubtful whether at the present stage of the industry there is enough certain information for such a treatise.

The other sections of this report deal with recent developments of methods employed in connection with rubber, sugar and cinchona. In each case it is assumed that the ordinary methods are known, and only those points are dealt with which are novel or of exceptional interest. Owing to the very large European planting population in the Netherlands East Indies and the Federated Malay States, very great strides have been made in agricultural research, far more than can be hoped for in many years in West Africa, and a description of such new methods and developments are of value and interest.

Information obtained by observation of methods evolved in one country is only rarely directly applicable to another country. This is particularly the case with cultivation methods, and for this reason any information in this report is of greater value as a source of indirect inspiration than for the actual direct commercial value of the facts described.

II.—GEOGRAPHY, POPULATION, &c.

(Figures given here are from a pamphlet "Facts and Figures about the Netherlands East Indies," published by the Department of Agriculture, Buitenzorg, and from the British Colonial Office List, 1926.)

The area in which are comprised the Malay Peninsula and the Netherlands East Indies, including the Western Dutch portion of New Guinea, lies between 7 degrees north and 11 degrees south and between 95 degrees and 141 degrees east, a total superficies of 3,500 by 1,200 miles.

The land areas and populations of the peninsula and archipelago are as follows :—

	Area in Square Miles.	Population.
Java with Madoera	50,752	34,984,712
Sumatra	163,145	5,852,135
Borneo	206,819	1,626,001
Celebes	48,060	3,108,337
Other islands	264,905	3,780,190
Malay Peninsula	56,602	3,358,054
	790,283	52,709,429

The European population of the Netherlands East Indies is given as 169,708, of whom there are 135,288 in Java and Madoera. The Europeans in the Malay Peninsula number 5,686.

In general, the climate is wet, the rainfall being controlled, as in India, Ceylon and West Africa, by two monsoons, westerly and easterly. The island of Java is subject to severe periodical droughts, and over the whole of the coastal areas there are elaborate systems of irrigation for the immense rice and sugar-cane industries. In the case of Sumatra, the rainfall is in general high and evenly distributed so that the agriculture of this island is rarely affected by drought. The rainfall of stations in the Governorship of Sumatra's East Coast, in which is centred practically the whole of the new oil palm industry, has been clearly summarised in a *Bulletin* * issued by the Royal Magnetic and Meteorological Observatory in Batavia. In this *Bulletin* the figures from 357 stations show a maximum reading of 6,676 millimetres (262.83 inches and a minimum of 1,700 millimetres (66.93 inches), at Bandar Baroe and Kwala Goenoeng stations respectively. The best distribution was 211.3 wet days per year at Boekit Lawang and the poorest 82.0 wet days at Soengei Simoedjoer.

*" Rainfall in the Northern Part of Sumatra's East Coast " by Dr. J. Boerema (No. 11).

Some idea of the wealth of these fertile tropical areas my be gained by observation of the following figures :—*

Average Annual Trade for 5 years—1920–1924.

	Imports.	*Exports.*	*Favourable Balance.*
Java and Madoera	£49,919,000	£73,283,000	£23,364,000
Other Islands ..	19,713,000	50,895,000	31,182,000
Malay Peninsula ..	117,343,000	150,075,000	32,732,000

Of the average annual exports (£124,178,800) of the whole Netherlands East Indies, £25,306,300, or just one-fifth was non-agricultural.

On account of its degree of over-population, Java serves as a reservoir of labour for the rest of the Netherlands East Indies, Javanese labourers being employed in Sumatra and other islands on a system of indenture. The maximum period of indenture has been reduced on several occasions within recent years. and at present stands at one year, with a maximum re-engagement of 13 months upon expiry of the original contract.

*From *Bulletins* 27 and 30 of the Department of Agriculture, Industry and Commerce (Central Bureau of Statistics, Batavia).

III.—THE OIL PALM INDUSTRY.

The history of the introduction of the oil palm from West Africa into the Netherlands East Indies, and the story of its gradual rise from the position of an ornamental plant to that of a recognised agricultural crop of importance is given in a valuable publication issued in 1922 by the General Experiment Station of the Rubber Planters of the East Coast of Sumatra.* (AVROS)

This *Bulletin* contains sections on the history of the introduction of the palm, varieties known, methods of planting, upkeep of plantations, artificial pollination and its effects, estimates of age of palms, diseases, factory machinery for handling the crop, methods of packing and shipping, crop records available from AVROS experiments and elsewhere, and a very complete bibliography of references. It was the first, and still remains the only publication to serve as a guide to an intending planter of this crop.

In this publication the date of the importation of the oil palm into Java is given as 1848, and from 1853 onwards fruit from the four palms resulting from this importation were widely distributed in the Netherlands East Indies. From the beginning, the Government appears to have realised the possible commercial value of the palm, and from 1859 to 1864 a plot of 14 acres was established in Java and one of 3 acres in Sumatra. In general, however, the palm was used for ornamental purposes until 1910, when Belgian enterprise, under Monsieur Hallet's direction, embarked upon the establishment of plantations of the palm. By 1915 these plantations totalled 6,500 acres. Since 1917 the industry has expanded steadily as may be seen from the following figures given by Dr. Rutgers :—

	Total acres planted.
1917	6,500
1918	8,500
1920	17,100
1922	28,000
1924	46,794†
1925	60,350

*(AVROS) "Investigations on Oil Palms," by Dr. A. A. L. Rutgers and collaborators : AVROS Experiment Station, Medan, Sumatra. Price 10/-

†From Statistiek van Aanplant, Produceerenden Aanplant en Productie, 1924

The figures for 1924 do not include returns from the Handelsvereeniging Amsterdam, a Company which is recognised to have embarked on a large scale on the industry but which does not give information for publication.

During 1924 the value of the palm-oil (pericarp oil) exported from Sumatra was 2,185,000 gulden (£182,083).

Statistics for 1925 are not yet available; in July and August, 1926, the number of oil-palm estates, so far as could be ascertained, was as follows:—

Malay Peninsula	4
Sumatra	39
Java	1
	44

All of the Sumatra estates are situated in the East Coast Governship, but in 1926 two of the largest companies have obtained concessions on the West Coast amounting to a total of 200,000 acres with a view to future development. The industry is extremely unlikely to extend in Java where climatic and economic conditions are unfavourable, and it is to Sumatra that we must look for possible great expansion. The industry in Malay Peninsula is considerably behind that in Sumatra in area, factory methods and plans for future expansion.

The question whether the palm-oil industry is destined to pass from the phase of being largely a sporadic forest industry into that of a systematised plantation one is of vital importance. The case differs from that of rubber. Supplies of rubber obtainable from the forests of South America were totally inadequate for the demands, and the Eastern plantations were in the beginning supplementary to the existing forest areas, although they rapidly assumed a new importance with the development of entirely new applications of rubber. The requirements of the oil-trade have been adequately filled by West African supplies, in so far as quantity is concerned, and any rapid expansion of a plantation industry of oil palms is likely to lead to direct competition between the forest product and plantation output.

Two advantages are obvious in a plantation industry. The market is able to make forward estimates, and even contracts, for necessary supplies, and it can obtain oil of a standard purity. Both of these are important, particularly if the demand for fatty oils increases steadily, and in addition the question of purity is likely to be of greater importance as the manufacture of edible solid fats becomes commoner. Factories in the East are now able to turn out oil of a maximum content of 3% free fatty acid.

It does not necessarily follow that a plantation industry must oust a more primitive method of production. We have the case of the cacao industry in which plantations have been unable to compete with the system of small holdings. In this case however, the question of quality is of secondary importance; the market wants a great bulk of low or medium-grade produce.

The future of the palm-oil industry is therefore still uncertain. Any increased demand will probably have to be met by systematic plantations, and specialized demands for oil of standard quality can only be met by efficient plantation and factory methods.

In the case of two industries, the Dutch have gained a pre-eminent position within late years, and in these cases an outstanding feature has been the efficiency of their methods of marketing. The output and price of Java quinine are governed by an agreement between grower and market. The Java sugar industry has steadily increased in volume and efficiency while in British colonies the industry has deteriorated and become unprofitable, the secret of success in Java being the control of the market by a selling cartel. All Java sugar is sold by a committee or "cartel" appointed by the estates and each sale is apportioned proportionately between the estates. In the case of quinine the Dutch hold the monopoly largely on account of the climatic requirements of the crop, requirements which are filled by Java alone, but in the case of sugar pre-eminence has been due to efficient cultivation, manufacture and marketing in the face of severe competition and exceptional difficulties. Equally efficient methods might very well place them in a similar position with regard to palm-oil.

Methods of Cultivation.

The Dutch have benefited greatly by the fact that the type of palm first introduced into the East was of exceptionally good standard. All of the plantations in the Malay Peninsula, Sumatra and Java have been established in this so-called "Deli" type, and none of the later importations have proved to be of immediate commercial value.

For practical planting purposes the oil-palm is classified on the thickness of its shell. For fruit of the same size, it is clear that an increase in the thickness of shell means a corresponding decrease in size of the oil-bearing pericarp and kernel. The ordinary types vary progressively from those with immensely thick shells to those with practically no shell at all, and it is possible to find all gradations in the proportion pericarp : shell : kernel. The Deli type is therefore by no means uniform, the fruit varying from palm to palm in size, shape and composition, while the palms themselves differ very markedly in habit, rapidity of growth, characters of the leaves, &c., &c. The Dutch have realised this fully, and the larger companies have in their employ botanical officers whose duties consist in selecting and propagating desirable types. In addition,

AVROS Experiment Station is carrying out selection in the hope of producing a type with a thinner shell than the " Deli " while retaining existing good characteristics.

Some idea of the effect of discarding undesirable types and choosing good parents may be gathered from the fact that Nigerian palm fruits *contain* from 16 to 25% of their weight in pericarp-oil,* while the Sumatra factories are able to *extract* 30 to 31 per cent.

It is difficult, at this early stage of development of the industry, to lay down definite lines of work in selection of improved types, but certain broad general facts have emerged from the work carried on in the East. It is clear that the aim of selection is to produce the maximum yield of palm-oil per acre, and that this may be attained in several ways. A large yield of fruit per palm with a rather low percentage of oil in the fruit, or a comparatively small yield of fruit with a high degree of richness, or a good average yield of fruit of average richness will give the same results other factors being the same. Again, a large number of small bunches or a moderate number of larger bunches may give much the same results.

The work on the estates of the Société Financière Belge, Sumatra, may be taken as an example of the efficient work now going on in many parts of the Netherlands Indies. In this group the work is in the charge of Monsieur M. Ferrand, to whom much of the information retailed here is due.

In general, selection is made within the Deli type, the Société Financière having six or seven estates of this type from which material may be drawn. Individual palms which have been observed to give high yields are marked and their yields are recorded separately. Number of bunches produced each year, the weights of these bunches and the weights of fruit on the bunches are noted, and the percentage-weight of pericarp and " nuts " (shell plus kernel) taken for each bunch. It seems to be generally recognised in Sumatra that spherical shaped fruits are undesirable as they do not pack well on the bunch and the thickness of pericarp is reduced at the upper and lower ends of each fruit.

Self-pollination is not easy to secure, as the male and female flowers of the oil-palm rarely mature at the same time on the same individual. It is necessary therefore to handpollinate and to use pollen drawn from the male flowers of palms of good type. In the case of the work carried out by the Société Financière, the yield records of both male and female parent are known.

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*Chemical Investigations into Products of the Oil Palm, by A. C. Barnes, F.I.C., B.Sc., Department of Agriculture, Nigeria, 1924.

In the table opposite there are given the yield-records of a palm which has been selected as the best all-round individual on the estates of the Société Financière. This palm is between 11 and 12 years old, so that it has been in bearing for about 7 years. It is situated in an ordinary estate-field, and there are no external conditions observable which might cause the high yield. There has been no special treatment applied to this palm, other than that necessary for selection-work such as handpollination and bagging of flowers to prevent cross-fertilisation.

The progressive lessening in size of the bunches as the end of the fruiting season approaches is very evident in the table below. This appears usual and is due to temporary exhaustion of the palm after its maximum effort in the beginning of each season's crop.

Taking the average richness of the pericarp in oil as 55%, the yield of this palm has been 76 kilograms of palm-oil during the 8 months under review. An acre of such palms planted at a distance of 30′ x 30′ would yield 3,500 kilograms or $3\frac{1}{2}$ tons of oil. This record probably establishes a maximum for the acre-yield obtainable by means of selection alone.

In habit, this palm closely approaches the ideal towards which M. Ferrand is working; and it will be of interest to note the general character of its growth. The height is rather below the average, being about 15 feet to the fruit bunches, and the trunk is above the average in diameter, these two facts pointing to a greater degree of robustness and strength than is usual. Leaves very long and heavy, drooping towards their outer extremities, and having broad strong bases. The axils, or angles between trunk and leaf-bases, are roomy and wide, thus providing ample space for large bunches. The leaflets are wide and of a good, healthy, dark-green colour.

It does not, of course, necessarily follow that stoutness of trunk, strong leaves and wide axils should in all cases be associated with high yield of fruit, and these factors are to a large extent liable to be affected by the distance apart which palms are planted. Close planting results in tall, spindly growth, a small crown, vertically growing leaves with small axils and delicate stalks and leaflets, and it is improbable that a palm under these conditions can yield heavily. It seems certain, however, that, in the case of the Deli type of palm, there are great variations in the case of each of the characters noted and that these variations are independent of environment. If employed with a moderate degree of caution and discretion, observations of the method of growth and habit of individual are of very great value in the preliminary task of selecting or discarding promising parents for breeding, but in the end the amount of oil produced per acre is the sole criterion by which the results of selection should be judged.

YIELD RECORD OF SELECT PALM.

(Eight Months' Observation).

Bunches plucked.	Date plucking.	Weight of bunch. Kilograms.	Weight of fruit. Kilograms.	Fruit % bunch.	Weight of nuts.	Weight of pericarp.	Pericarp % Fruit.
1.	12. 9. 25	31.900	18.000	56.4	4.300	13.700	76.1
2.	,,	41.000	21.400	52.1	4.900	16.500	77.1
3.	18. 10. 25	23.900	14.800	61.9	2.300	12.500	84.4
4.	20. 1. 26	39.200	24.200	61.7	6.100	18.100	74.7
5.	5. 2. 26	26.300	19.000	72.2	4.400	14.600	76.8
6.	13. 2. 26	35.400	21.400	60.4	5.900	15.500	72.4
7.	17. 3. 26	33.800	19.600	57.9	7.500	12.100	61.7
8.	7. 4. 26	32.500	17.000	52.3	4.600	12.400	72.9
9.	30. 4. 26	27.700	15.400	55.5	3.800	11.600	75.3
10.	20. 5. 26	17.000	7.500	44.1	2.000	5.500	73.3
11.	20. 5. 26	19.700	8,200	41.6	2.200	6.000	73.1
Total ..		328.400	186.500	—	48.000	138.500	—
Mean ..		29.85	16.95	56.0	4.36	12.59	74.3

N.B.—A kilogram equals 2.24 pounds.

The Société Financière has kindly undertaken to forward 200 seeds, from selected bunches and of known male parentage, from the palm described above for trial in the Gold Coast. This should be enough to plant from one to two acres. No amount of importation of selected types, however, can have the same effect as systematic selection of desirable local types and discarding of undesirable ones. The Dutch have already reached the stage of having established large areas of a uniform, good type from which new and better variations may be chosen. Their new plantations are being established from nurseries of selected seed from selected bunches from selected parents, the older plantations are being divested of undesirable palms, and the whole standard of the industry is rising surely and rapidly. The skilled work of selection and breeding is to a large extent in the hands of European scientific officers employed by the companies, and seed of good strain is eagerly sought by the planters.

The Young Plant.

The germination of the oil-palm seed is very slow and uncertain unless some procedure is adopted to speed the process up. The preliminary work of investigating convenient and efficient methods towards this end has been done by the AVROS staff and has been described by Rutgers ("Investigations on Oil Palms"). Practically all the methods which are simple enough to be generally adopted are based on application of heat to the seed. Better results are obtained from seeds than from the whole fruits.

The most primitive method consists in heating the cleaned seed by means of fermenting dung. The seeds are placed in a pit about 3′ cube, some 20,000 seeds sufficing for a pit of this size, and a covering layer of fresh dung added to fill the pit. In some cases the dung is mixed with sand, to reduce the maximum temperature of fermentation. After a week the seeds are taken out of the pit and planted out in germination beds.

A cleaner and more efficient method of heating the seed is used on the larger plantations. It is based on methods evolved by AVROS station. The cleaned seed is immersed in water and the water brought up to a temperature of 45°-50° C. three times a day. The seed remains in the water during the whole time of heating and cooling and is thus subjected to a long process of soaking combined with periodic warming. After 8 days of this treatment, the seed is removed for planting in the nursery. Estates claim that by this method germination begins in 3 months and is complete in 6 months, an average of 80% successful germination being readily obtain. Seeds which germinate after six months in the beds are looked on as undesirable or defective and are discarded.

Rutger's tables shew 60% germination obtained by this method in 9 months and 84% in 12 months, against 25% in ten months obtained by planting fruits (with pulp), and 49% in 9 months by planting untreated seed (without pulp).

The treated seed is set out in nursery-beds, being placed at intervals of 3 or 4 inches in lines 8 inches apart. In most cases, the germinated seed is transplanted from these germinating-beds into a second set of beds. This second transplanting is at much wider spacing, the germinated seeds being placed 8″ to 12″ apart in lines which are 18″ to 24″ apart. From these beds, the young plants are taken into the fields just after their first and second divided leaves appear.

Contrary to what would be expected from a palm, oil-palm seedlings stand a considerable amount of rough handling, although it is obvious that they must suffer to some extent. In many cases the seedlings are dug up from the nursery and transported for journeys of 2 or 3 days in railway-vans, no wrapping or packing being employed. The loss rarely appears to be very great. On numerous occasions plants have been left too long in the nursery or have been set out at wrong distances in the fields, and transplanting of these plants, sometimes 2 to 3 years of age, has been carried out without deaths. This characteristic is of interest and frequently of use, but the practice should be avoided as much as possible.

In the climate of Sumatra, experience has shewn that 9 metres is the optimum distance at which oil-palms should be set out in the field (9 metres = 29.5 feet), and there seems no reason against this distance being adopted in the moist areas of the Gold Coast. The sole estate in Java, where the climate is drier and the palms much smaller, affords evidence that the distance should be slightly lessened where optimum climate conditions do not prevail.

On one estate in Atjeh (northern part of Sumatra) the mistake was made of planting at a distance of 12 metres (39.3 feet) apart, the palms being arranged in equilateral triangle position. As the palms here are now from 7-12 years of age it is almost impossible to increase the number per acre without causing harmful overcrowding in some lines and wasteful overspacing in others.

Some idea of the wastage of space following on too wide a system of planting can be gained by observing the following figures :—

System of planting.		*Number palms per acre.*
29.5 ft. x 29.5 ft.	square	50
do.	triangular	58
39.3 ft. x 39.3 ft.	square	28
do.	triangular	33

Field Methods.

Three points of exceptional interest become evident after a visit to the established plantations of oil palms in the East Indies ; these are the complications which arise owing to the presence of lalang

grass (*Imperata cylindrica*) as a common weed, the progress that has been made here in contrast to other tropical countries in the matter of discovering and utilizing new types of leguminous green dressings, and the reversal of opinion in the matter of pruning away leaves of the palm.

In the Federated Malay States and in Sumatra, land which has been for some time cleared of forest becomes covered with a heavy growth of lalang grass. Usually this grass stands 4 feet in height or more and its growth is as dense as that of a lusty field of rice. The rhizomes or underground horizontal stems of the grass travel through the soil to a depth not far short of a foot and up to the present no other plant has been found which can sustain a successful struggle against a full stand of lalang. The cost of clearing land from this pest is enormous, as the soil has to be dug over completely to a depth of a foot and all root-stocks removed, the expenditure per acre ranging up to £10.

The presence of this grass has brought about a variety of methods of cultivating the young plantations of oil palms and other perennial crops. In earlier days all efforts were directed towards keeping the soil completely clear of all weeds, and in Ceylon, the Malay States and the Netherlands East Indies can be seen many proofs of the appalling loss of soil and of crop which followed on a too rigid adherence to the system of clean-weeding. Terracing of slopes, the employment of catch-drains and silt-pits or mould-traps, strip forking have all been tried as remedies for or preventives of soil-erosion. Several striking cases of the harmful effects of clean-weeding on young oil palms are to be found on the plantations in Sumatra.

At the present time, there is no clean-weeding practised in Sumatra or the Malay Penisula. Two practices have arisen to replace it. In the first, the whole field is cleared of lalang by deep hoeing and the land planted up with a leguminous green dressing. In the second, which is cheaper and is very much criticised locally, wide lines are cleared of lalang, the lines planted with young palms and the inter-lines left covered with lalang: from time to time the interlines are widened by further hoeing until by the time the palms are mature all the lalang has disappeared.

This second method, in spite of criticism to the contrary, is capable of giving excellent results. Its advantages are speed in planting and a more tolerable incidence of expense. The palms can be set out much earlier on a greater area, and the expense of hoeing is spread over four or five years. The method is being used on a very large scale on certain estates of the Société Financière in the southern part of Sumatra's east coast. A somewhat similar method has always been employed successfully for establishing cacao in some of the West Indian Colonies, with the difference

that it is not necessary there, in the absence of lalang, to hoe, periodic cutlassing of the weeds being found sufficient. It is clear that, for the method to be employed without harm to the young palms, the hoed lines must be from the first of ample width and they must be promptly widened progressively with the increase in size of the growing palms. At no time should the palms and the lalang be in actual competition for light and soil. In the case mentioned above the planting-lines are now 3 metres ($9\frac{3}{4}$ feet) in width in the first year, and are 8 metres ($26\frac{1}{4}$ feet) apart, and the inter-lines of 5 metres ($16\frac{1}{2}$ feet) disappear in 5 years.

The search for green-dressings has resulted in the establishment of two plants of immense value in Sumatra. One of these, *Calopogonium mucunoides*, is very generally used in young rubber and oil-palm cultivations, and the other *Vigna oligosperma* is employed under the heavy shade of old rubber and old palms. Both are vines, the former a lusty grower which forms a close, heavy layer 2 to 3 feet thick over the ground, the latter a frailer, slighter plant which will grow in comparatively dense shade and covers the ground with a uniform carpet as close and smooth as turf.

These two plants have revolutionized the methods of cultivation of perennial tropical crops in Sumatra. *Calopogonium* will not overcome lalang, but effectively prevents it from invading clean land. It spreads with amazing rapidity, and newly cleared forest-land can be covered with it long before any danger arises of the entry of lalang. It is a common sight in Sumatra to see areas of several hundreds or even thousands of acres covered with a thick, even layer of this fine green-dressing, the soil effectively protected from erosion and from weeds and the content of nitrogen in the soil gradually being increased. It has the disadvantage of dying back in the dry season, but seeds itself out with rapidity with the first rains.

It is too early in the history of the industry to expect final statements concerning the correct methods of manuring. These problems are receiving attention in Sumatra and the Malay Peninsula, however, and some information should be available in the course of a few years. As information obtained in the East is hardly likely to be directly applicable without modification to other places, it is clearly necessary that plans for the improvement of the industry in West Africa should include carefully controlled manurial trials.

In this connection, mention should be made of the controversy now going on over the conclusions concerning the industry arrived at by Monsieur Yves Henry, the Director of Agriculture in French Indo-China. As the result of observations made in Sumatra, M. Henry points out that the yields of oil-palm plantations decrease

with fair rapidity from the age of 10 to 12 years.* There is no gainsaying the accuracy of the figures published by M. Henry or the correctness of the conclusion he arrives at : his figures are actual crop-records supplied to him by estates, and in all cases the diminution in yield is evident.

While there is no doubt regarding the accuracy of M. Henry's figures, there is a strong feeling, among those interested in the development of his new industry, that his explanation is open to question. A rejoinder to his article is being prepared by the AVROS staff in conjunction with estate workers, so that there is no need to enter into details here. At the same time, some criticism is necessary lest the impression remain that the productive life of the oil palm is a short one.

We have the actual fact that oil-palms both in Sumatra and in Africa live and produce fruit for a very long time, certainly more than 50 years, and probably for a century. The same is true of rubber, coconuts, nutmegs, cacao and most other large perennials. It is natural that any tree should rise to a maximum of productivity and then gradually decline, and it is felt to be unreasonable to believe that this maximum should be reached in 10 to 12 years by a plant such as the oil-palm whose usual life is certainly not less than 50 to 100 years.

The probable explanation of the early decline in yield noted by M. Henry lies in the fact that correct cultural methods were not known, and are not yet fully known for the oil-palm by those who embarked on the industry. Early procedure naturally aimed at bringing the palms into full bearing as early as possible. Wide planting, good cultivation, pruning, artificial pollination,—in other words, direct stimulation of each individual palm,—have brought the plants into early and high productivity. The decline which follows is the natural outcome, and in this case has been hastened in some cases by over-exhaustion, in many cases by initial errors of field-work, such as wrong distance of planting, clean-weeding, or too severe pruning, and in all cases by postponement of systematic manuring until reliable information becomes available. There is no evidence whatsoever against the feasibility of sustaining and increasing the average of high productivity of the oil-palm by sound cultivation and manuring.

The early practice of pruning away all leaves below the bunches of fruit has been proved by the AVROS staff to be harmful, and is not followed now on any estate. It arose partly from a desire for neatness and for convenience in reaping the fruit. In addition it was thought that vigor and nourishment which go normally into the prolongation of the life of the leaf would be available for greater production of fruit. The leaves in any event are deciduous and fall away as the trunk grows upward. The actual result of unduly severe pruning has been twofold : in the first place it has greatly

*"Documents sur le Palmier à Huile à Sumatra," by Yves Henry, Hanoi, Indo-China, 1926.

increased the rate of growth of the palm, and secondly it has weakened the plant and diminished the yield of fruit. On all of the older estates may be seen areas in which the palms gradually lessen in diameter of trunk as a result of severe pruning, and then gradually resume their normal diameter ofter cessation of the practice. This " hour glass " shape of trunk is visible evidence of the harm that can follow severe pruning.

Actual and Prospective Yields.

The need for systematic manuring is fully realised in the East, and every large plantation is conducting trials which supplement the AVROS experiments. In most cases, there has not yet been time to obtain definite, reliable information on the subject, but several general indications have evolved from the trials so far. On one estate in Malay (Tennemaram) good results are claimed from the use of animal guano which is cheaply and easily obtainable from local caves. The soil here is a deep peat which is doubtless rich in nitrogen and which is naturally fertile when efficiently drained.

On Poeloe Radja estate in East Sumatra, there are large areas of poor soil, and the growth of the palms has been poor and weakly. Marked yellowing of the leaves, slow growth and poor productivity are evident on these areas. Dr. Fickendey's investigations tend to show that deficiency of nitrogen is a major cause of the trouble, and definite results have been obtained from nitrate of soda and sulphate of ammonia. Phosphoric acid, in the form of basic slag, has also had good effects, while Kainit (potassium salts) has been without result.

Practically no figures are available yet on this subject, and the AVROS staff have been obliged to base their trials on the ascertained requirements of the palm as shewn by chemical analysis of leaves and fruits. The annual consumption, in one year, of plant-food required by the palms is given as follows :—

*Weight in pounds per acre.**

	Nitrogen.	*Potassium.*	*Phosphorus*
Leaves and fruit stalks	99.2	154.2–199.7	34.1–56.9
Fruits	20.0	21.8	7.7
Totals	119.2	176.0 to 221.5	41.8 to 64.6

These figures serve as a basis on which field-trials may be devised.

Artificial Pollination.

During the early stages of the founding of a plantation oil-palm industry, a great deal of attention was given to the possibility of increasing the crop by deliberate pollination of the flowers. The

*Converted from kilograms per hectare from tables in Rutger's " Investigations on the Oil Palm," p. 44.

point is of exceptional interest. Methods and results have been described by Rutgers and enough information has been since obtained to enable a planter to decide on the advantages and disadvantages of the procedure.

The pollen, or male element, of the oil-palm is wind-borne, and under even the favourable conditions of a uniform regular field a large percentage of the female flowers are not fertilised and do not produce fruit. The case is further complicated by the facts that only rarely do the male and female flowers ripen at the same time and on the same palm, and that the production of male and female inflorescences varies enormously, from palms almost entirely male to others preponderantly female. The disproportionately small numbers of fruits formed in relation to the flowers produced does not seem to be more marked in the case of the oil-palm than with other crops,, such for example as sugar cane or cacao or coffee, and no doubt the oil-palm possesses the usual power of discarding even fertilised flowers when the burden of building up an excessive crop of fruit becomes too great.

The immediate response in increased production of fruit, which follows on deliberate hand-pollination in the case of the oil-palm, seems due to two factors. In the first place, it is probable that under natural conditions the oil-palm is not pollinated as fully as can be easily borne. In the second place the palm, at least in the early stages of its life, appears to have a greater power than is usual with most plants of calling up reserves of strength to cope with an artificially induced increases of crop. That the effort is followed by exhaustion has been proved on nearly every estate in Sumatra by a marked diminution of crop in subsequent years.

In the experiments at Mata Pau estate reported by Rutgers, an increased production of 158% ($2\frac{1}{2}$ times the yield) is mentioned as the result of artificial pollination. This is unusual, but every estate in Sumatra reports increases of from 25 to 50% in the course of their trials of this procedure. As a result of experience, which indicates a rapid exhaustion of the tree from over-production, the practice has been discontinued or modified in practically all cases.

There is some evidence that the revulsion of feeling in this matter has gone too far. It seems fairly certain that less fruits are produced naturally than can be borne without undue strain by the palm. It seems equally certain that deliberate pollination leads to a greater production than the palm can bear without subsequent exhaustion especially if the procedure is used on young, growing palms. In all probability some artificial pollination will be found necessary and profitable, particularly where efficient manuring increases the vigor of the palm while the natural pollination remains unaltered in speed and efficiency.

An interesting modification of the procedure is being used on one estate (Semadam). Normally, the collected pollen is squirted direct, or dusted by hand, on to the opening female flowers. This means that practically every flower is fertilised and an exhausting

increase of crop effected. On Semadam a moderate increase of about 10% is claimed when less complete pollination is practised. A pollinating-machine is used by which pollen is blown into the air in comparatively small quantities, the distribution being effected down the middle of the inter-lines of cultivation. The consumption of pollen is 125 grams per 60 hectares (say 5 ozs. for 150 acres.) The underlying idea is to supplement the amount of pollen normally carried by the air, and to be content with a reasonable but regular and constant annual increase.

This machine appears to be efficient so far as the economical distribution of pollen is concerned. It consists of an airchamber with inlets from two bellows and a vertical distribution tube ending in a nozzle. The position of the inlets and the insertion of necessary baffles results in a current of air travelling spirally up the tube and carrying pollen with it. The nozzle consists of an inverted cone fitting loosely into a conical casing, and through the circular aperture between cone and casing the pollen is ejected in a very fine cloud. It is possible that the procedure increases the number of flowers which are fertilised by supplementing the pollen which is normally borne by the air, but the problem of adjusting the crop to the potentialities of the palm is brought no nearer to a satisfactory solution.

It is clear that experience alone will enable a planter to decide on the safest and most efficient routine-method of artificially pollinating his palms. As more accurate records of yields become available and as the degree of response the palms make to improved methods of cultivation and manuring is more clearly understood, it will be possible for each estate to devise a system and degree of pollination most suited to the prevailing conditions. The actual technique of hand-pollination is simple, and Rutgers regards it as quite feasible for one labourer to examine and pollinate 500 to 1,000 palms in one-eight-hour day. Pollen may be stored in sound condition for periods up to 6 weeks by keeping it in desiccators over unslaked lime, and its soundness can be judged by the presence or absence of the smell of aniseed which is emitted by normal sound pollen-grains.

Yields.

Past mistakes in methods of cultivation and ignorance of the effects of manuring stand in the way of any attempt to estimate the probable yield per acre of oil. In addition, it is difficult to obtain existing figures from commercial estates. Certain maxima and minima of yield have been established with a fair degree of certainty, however, and probable general yields can be estimated.

In the following Tables are given the records of two properties in Sumatra. The first (Bah Bajoe) consists of 54.4 acres of the "Deli" type, the second (Rambong Sialang) of 410 acres of the same type. Bah Bajoe is on first class soil and the palms are among

the best seen, but no systematic cultivation is carried on and no hand pollination has ever been attempted. Rambong Sialang on the other hand has a past history of severe leaf-pruning which did considerable harm, and the palms were hand pollinated in 1921, 1922 and 1923.

Yields on Bah Bajoe Estate.

(54.4 acres Deli type planted in October—December 1917: planting distance 28′ x 32′. Total number of palms 2,494 or 46 per acre).

Pounds weight of pericarp-oil per acre.

Month.	1923.	1924.	1925.	1926.
Jan. ..	—	245	173	204
Feb. ..	—	103	160	162
Mar. ..	—	—	103	186
April ..	108	—	39	92
May ..	—	90	64	245
June ..	169	108	130	193
July ..	275	131	117	293
Aug. ..	111	250	212	
Sept. ..	203	193	203	1,375
Oct. ..	145	220	173	
Nov. ..	195	182	166	
Dec. ..	136	198	171	
Totals ..	1,456	1,720	1,711	

Yields on Rambong Sialang Estate.

(410 acres of Deli type planted in 1913–14: planting distance 36′ x 36′. Total number of palms 13,760 or 34 per acre).

Pounds weight of pericarp-oil per acre.

Month.	1924.	1925.	1926.
Jan.	34	120	92
Feb.	59	112	143
Mar.	92	121	173
April.. ..	75	108	124
May	59	118	119
June ..	48	105	102
July	53	90	103
Aug. ..	43	116	
Sept... ..	78	139	856
Oct.	91	173	
Nov. ..	105	169	
Dec.	112	227	
Totals ..	849	1,598	

The figures for Bah Bajoe were originally given in kilograms of fruit reaped from the total area. In converting fruit into pericarp oil, a ratio of 30% was used. The Rambong Sialang figures were originally given in kilograms of oil reaped from the total area. The two sets of figures are not quite comparable as the oil at Rambong Sialang was expressed in 1924 and 1925 by a handpress which would hardly give an extraction figure of more than 25% : the figures for those years should therefore be increased by one-fifth to give a valid comparison.

The AVROS table of estimated yields at different ages was compiled in 1922 * and in calculating oil present into oil extracted the factor 80% was employed. If the factor 90% be employed, to accord more with results obtained in recent factories, the following figures are obtained :—

Age.	*Pounds pericarp-oil per acre.*
4th year	702
5th—7th year	1,404
8th—10th year	1,579
11th—20th year	2,086
21st—30th year	2,086
Over 30 years	1,230

The following comparison is interesting :—

Pounds pericarp-oil per acre.

	AVROS. Estimate.	*Bah Bajoe. Crop.*	*Rambong Sialang. Crop.*
6th year ..	1,404	1,456	—
7th ,, ..	(1,491)‡	1,720	—
8th ,, ..	1,579	1,711	—
9th ,, ..	(1,632)‡	—	—
10th ,, ..	(1,885)‡	—	849
11th ,, ..	2,086	—	1,598

In general, the impression that prevails in Malay and Sumatra regarding probable yields is an exaggerated one. Practically everyone assumed a likely yield in mature fields as one ton of oil per acre. The best field at Poeloe Radja Estate in 1925 yielded 2,000 kilogrames per hectare (1,820 pounds per acre). At Nijkerk estate, the five-year old plantations yielded 480 kilograms per hectare (430 pounds per acre). It is quite possible that in the future yields of a ton per acre will be obtained in mature fields

* "Investigations on Oilpalms" by A. A. L. Rutgers, p. 111.

‡ Interpolated figures.

planted with improved types and efficiently manured and pollinated, but this cannot be assumed under present conditions. Figures at AVROS, Poeloe Radja and Bah Bajoe indicate three-quarters of a ton as a likely yield on fields slightly above the average in fertility, and there is little reason to doubt that this figure would also be attained by efficient planting-methods in suitable parts of the Gold Coast. The existing forests of mixed types, even where the palms are not mingled with other forest-trees, are likely to give yields considerably below this. On this point information will be soon available from the cleaned areas supervised by the Department of Agriculture in the Gold Coast.

Manufacture.

In devising machinery for the efficient production of pericarp-oil on the Eastern plantations the following processes have had to be considered :—

(1) Transport of fruit to factory.
(2) Weighing the fruits.
(3) Sterilising the fruits.
(4) Stripping fruit from bunches.
(5) Sifting chaff from fruit.
(6) Boiling fruit in malaxeurs.
(7) First pressing of oil from fruit *or*
(8) Centrifugalling oil from fruit.
(9) Separating partly exhausted fibre from nuts.
(10) Second pressing of oil from fibre.
(11) Benzene extraction of residual oil from fibre.
(12) Transport of fibre to furnaces.
(13) Drying the nuts.
(14) Cracking the nuts.
(15) Separating kernels from cracked shells of nuts.
(16) Transport shells to furnaces.
(17) Drying the kernels.
(18) Purifying the oil by steaming, washing and skimming.
(19) Separation of oil from water.
(20) Filtering the dry oil.
(21) Separating traces of water by centrifugalling.
(22) Recovering traces of oil from wash-waters, scum, &c.
(23) Packing and transport for shipment of oil and kernels.

Among these processes there are six which have given rise to a considerable amount of difference of opinion, if not actual controversy. The points at issue may be stated as follows :—

(*a*) The relative merits of sterilising whole bunches, before stripping off the fruits, and of sterilising the fruits alone,

(*b*) The necessity or otherwise of " depericarping ", that is removing the oil-bearing pericarp of the fruit before extracting the oil,

(*c*) The relative merits of pressing and of centrifugalling the oil from the fruits,

(*d*) The feasibility of extracting the last traces of oil from the pericarp by extraction with benzene,

(*e*) Efficient and cleanly method of separating kernels from cracked shells,

(*f*) The use of a centrifugal separator for purifying the expressed oil.

In the most recent factories, just completed or now in course of erection, in Sumatra, the main points of these controversies have been settled for the time being, and the conclusions arrived at there are based on the ripest experience available and therefore worthy of close attention.

There is only one oil-palm factory in the Malay Peninsula which has any pretensions to reasonable efficiency, namely Tennemaram, an estate of 1,700 acres of mature palms. The other two properties visited, Hopeful and Elmina estates (800 acres and 2,000 acres respectively), are carrying on in a primitive fashion until certain of the most efficient machinery. The oil extracted per cent weight of fruit handled is 24.8%, 22% and 19% respectively at these three factories. The first and second extract with centrifugals and the third with a screw-press.

In Sumatra on the other hand several new and well-equipped factories have been completed recently or are in course of construction. All of these are by Krupp & Co., and most of them are erected for an output of 10,000 tons of pericarp-oil per annum. Poeloe Radja, Nijkerk, Marihat, Songei Lipoet, Mata Pau, Tanah Hitam Oeloe, Tindjowan, and Tanah Gamboes are the up-to-date factories operating at the present time, and all of these use hydraulic presses which in five cases are followed by benzene extraction. The methods of extraction differ in each case, the main methods being

(1) One heavy pressing followed by benzene extraction,

(2) Two moderate pressings, one of whole fruits and one of fibre, followed by benzene extraction,

(3) One light pressing of whole fruit followed by heavy pressing of fibre.

Tanah Hitam Oeloe claims 25% extraction (oil% fruit) in one heavy extraction, Poeloe Radja 25% in two moderate pressings, Songei Lipoet 20% in first press and 5% in second, Karang Inoue 23.8 in one pressing, while Nijkerk and Marihat claim that 90% of the oil obtained is extracted in the first press, 5% in the second and 5% in the benzene extractors.

The type of first press universally used is a new model by Krupp. It contains twin cylinders working on a swivel, so that one can be filled while the other is in operation. By means of a sliding-cover it is possible to give a first light pressing, increase the charge and re-press. The twin-press is operated by one man who does the filling, pressing and discharging single-handed, and from 12 to 14 charges per hour is the usual rate. The charge of each cylinder is 60 kilos of fruit, so that three-quarters of a ton of fruit per hour is handled by the twin, the capacity of each cylinder being 12″ depth by 18″ diameter. Pressure varies according to the general process followed and ranges from 150 to 350 atmospheres. As the pressure is applied from below, discharging of the finished load is automatic, being effected by the hydraulic piston.

The second presses are of the vertical frame type and are of greater capacity than the first presses. Pressures ranging from 150 to 350 atmospheres are used, varying with the subsequent treatment followed.

The efficiency of these methods is judged from the ratio *oil extracted % oil present in fruit*. At Poeloe Radja, Dr. Fickendey claims an efficiency of 99% for double hydraulic pressing followed by benzene extraction, and this figure appears not only credible but reasonable when one considers the ease with which complete exhaustion can be effected by an ordinary laboratory extraction apparatus.

In the present early stages of the industry, estates will not publish their figures, nor even disclose them in confidence as many of the methods are still in the experimental stage. For the present, therefore, all that can be said is that no case of efficient extraction by centrifugals can be found, and that every factory in Sumatra has condemned the method and has adopted hydraulic pressing followed by benzene extraction as the more promising and profitable procedure.

It will perhaps do no harm to place on record the fact that every modern innovation in the matter of palm-oil production in the East has up to the present been made by Krupp & Co. This firm has resident engineers in Sumatra and Java, experiments on a large scale with new types of machinery, and has succeeded in co-ordinating the results of investigations into efficient factories. They control and run their factories for a year before handing them over to their customers, and give information willingly to enquirers. Few signs of enterprise are evident from English firms, with the solitary exception of Messrs. Manlove Alliott & Co., of Nottingham, and this firm appears to have pinned its faith to the centrifugal method without making any continuous experiments on the spot.

The sterilization of fruit before extraction of the oil has always presented difficulties, and the problem cannot be said to have yet been solved in an entirely satisfactory way. Following are some of the methods used :—

(*a*) Fruits ripened in fieldsheds after reaping, the loosened fruit beaten from the stalks with hand-flails, and the fruits sterilized by immersion in steamed tanks in the factory.

(*b*) Fruits separated from stalks in the factory, using a mechanical stripper, and then sterilized by immersion.

(*c*) Whole bunches sterilized in the factory in railway-trucks, and then separated by mechanical strippers.

The first two are unsatisfactory, and unless unusual rapidity is insisted on a high degree of free fatty acid results. In several cases a modification of the second method, whereby whole bunches are transferred from railway trucks into sterilization chambers, has been tried, but the cost appears to be high. A surprising lack of ingenuity appears to have characterised many of these efforts, and loading and unloading by gravity has been almost entirely neglected.

In the most recent of Krupp's factories, the fruit-bunches are conveyed to the factory in steel basket-trucks by rail. The trucks are whipped up by cranes, which automatically weigh them, and packed into large steel sterilisation chambers. Each chamber holds six trucks. After an hour's sterilisation the chamber is opened, the trucks run out and the fruit tipped into endless conveyors and carried to the strippers. This method seems to be the most efficient yet devised, and when certain minor drawbacks, such as inefficient types of chamber-doors, have been removed, it will probably become universal in well-equipped factories. In the existing factories, free fatty acid can be kept below 2% as compared with from 10 to 40% in native West African oils.

In no case in Malay or Sumatra is de-pericarping of the fruits practised, and it may be regarded as definitely discarded. The work of the malaxeurs, or stirring-vats, in which the fruit is boiled before pressing is so thorough that most of the pericarp is separated from the nuts during the 20 minutes of stirring and boiling, and in addition a considerable percentage of the oil is set free. The malaxeurs in common use have a capacity of about $\frac{3}{4}$ of a ton and an internal measurement of $6' \times 2\frac{1}{2}'$. In one case (Rambong Sialang) the malaxeurs were preceded by a "steam-box" which was interposed between sterilisation-chamber and malaxeur, and very efficient pressing appeared to result.

The processes for purifying the expressed oil are complicated. Four grades of oil may be distinguished, namely that from the first presses, that from the second presses, residual oil extracted by benzene, and lowgrade oil recovered from scums, emulsions and other sources of possible loss. These grades are packed and shipped separately.

The necessary processes of purification include :—

(*a*) Washing with injected steam and added water,

(*b*) Separation of oil and water in settling-tanks,

(*c*) Recovering oil from the emulsion (which forms at the surface of contact between oil and water) by means of a centrifugal separator.

(*d*) Drying of the separated oil by boiling in steam-cased vats.

(*e*) Filtering the dried oil in horizontal scum-presses to remove solid impurities.

(*f*) Recovering oil from waste by steaming, washing and settling.

Excepting in the most recent factories, only the two first of these procedures are followed, but, with the example before them of the amazingly efficient methods of their sugar factories and the increasingly high recovery attained thereby, the Dutch are not likely to tolerate wastage in their oil-factories, and the perfecting and adoption of necessary machinery is only a matter of time.

The centrifugal method of purifying oil by use of a separator closely akin to a cream-separator * does not appear to be of general application. At Marihat and Poeloe Radja it is used for removing water from the emulsion of crude oil and water before the oil can be passed through the filter-presses : the presence of a water-film blocks the apertures of the filter-bags. For rapid, economical work, the horizontal filter-press, which is universal in sugar factories, has been adopted in Sumatra for palm-oil.

The problem of separating broken shells from kernels is one which has been solved only recently. Up to a year ago the use of clay-baths, of such a density that shells sank and kernels floated, was universal. The more cleanly method of employing a strong solution of brine has been discarded on account of the cost : the charging of a small brine-separator costs 500 to 600 gulders (say, £50) in Sumatra. The extremely unpleasant smell and the general messiness of the clay-bath make it unsuitable for a well-equipped factory which prides itself on efficiency and smartness, and in addition the process is discontinuous and therefore too slow and laborious.

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*See " Mechanical Processes for the Extraction of Palm-oil " by A. C. Barnes F.I.C., B.Sc., Department of Agriculture, Nigeria, 1925.

The new Krupp factories at Marihat, Nijkerk, Poeloe Radja, and Tindjowan in Sumatra and the solitary factory in Java are equipped with an elutriator or ' under water shaker ', from which an efficiency of 97% separation is claimed. This figure is higher than the clay-bath method. The principle of the machine is as follows. A steel basket into which the shells and kernels are fed moves rapidly up and down inside of the outer tank : the bottom of the basket slopes slightly downwards to the front end and in addition is slightly sloped to one side ; to slow down the forward movement of the shells and kernels the basket is fitted with shallow cross-buffers, and shells and kernels are slowly impelled forward over these obstacles by the up-and-down motion of the basket. The heavier shells are progressively urged to the lower side of the basket while the kernels remain for the most part on the upper half. At the lowest end of the basket are two bars of different heights, the higher one on the upper slope of the basket. Over the lower bar the heavier shells are impelled and fall into a separate receptacle outside from which an endless belt carries them to the furnaces. The kernels on the other hand are impelled over the upper higher bar into another receptacle which delivers to the driers. Pure water is of course used in the tank. The whole process depends upon the adjustment of the stroke and speed of the up-and-down movement of the basket to the heights of the final bars : the shells are thrown to a height just short of that of the higher bar while the lighter kernels surmount the obstacle.

Most of the other machinery is simple and detailed description is not necessary here. The strippers are all of the ordinary type. namely rollers or cylinders fitted with substantial flails and set so that the threshed fruit but not the bulky stalks can pass between the rotating flails. Rotary sloping cylinders of " expanded metal" or wire-mesh are used for separating fibre from nuts after the first pressing, the fibre falling through the mesh while the nuts move slowly down the cylinder to the terminal outlet.

Mention might be made here of the projected use of a horizontal screw-press by Poeloe Radja Estate as a possible substitute for the first hydraulic press. Dr. Fickendey is planning to instal a modified screw-press similar to the Anderson press used for oil-cakes. The machine is stated to be continuous in operation, working on the principle of an Archimedean screw, and, if it can be applied to oil-palm fruits, it should offer many advantages.

The benzene-extraction machinery used in Sumatra factories is made by A. Borsig, Berlin-Tegel, Germany. It is complicated, consisting of the following parts :—

(*a*) Extraction-vessels,
(*b*) Still with condensing arrangements,
(*c*) Separating towers for separating traces of benzene from palm-oil,
(*d*) Benzene-purifiers.

The apparatus has to be mounted in a building well away from the factory or other sources of danger from fire.

Packing and Transport.

At Tennemaram, Hopeful and Elmina estates in Malay, and in the more primitive of the Sumatra factories, the oil is packed in 40 gallon casks. The method is very expensive, and at Tennemaram the cost is stated to be £6 per ton or one-third of the total f.o.b. expenses. The other two-thirds comprise about £6 per ton freight-charges, and £6 for manufacture and local transport.

The larger Sumatra factories ship their oil in railway tank-waggons of 7 tons capacity. These cylindrical tanks are whipped on board the steamer and emptied. Plans are now in hand for the erection of large tanks, on the same lines as petroleum tanks, at the ports of shipment, in which oil from the estates will be kept until arrival of the tank-steamers. It is stated that this method of bulk-shipment is also being employed by Belgian concerns in the Congo Belge.

Erection of a Factory.

In any modern factory, so much depends upon the correct co-ordination and balance of the various parts that it is unwise to accept the plans and details of anyone but a skilled firm of engineers with specific experience. This is even more necessary in the case of an oil-palm factory, where the industry is still in an experimental stage and the methods and machinery are likely to be improved and modified for many years to come.

At the same time, the engineer needs definite data and prescriptions on which to work. Capacity of the factory, area of the plantation, definition of the exact methods to be provided for, speeds at which the various component parts of the process will be worked, are some of the points which must be decided by the client and not by the engineer. The broad outlines of an efficient oil-palm factory are known at the present and it is comparatively easy to indicate what is wanted. But neither in the case of an oil-palm factory nor in the case of any other factory of similar complexity should the onus of co-ordinating various processes and obtaining an efficient, economic unit be laid on the shoulders of any-one but an experienced construction engineer.

From observation of the industry in the East, it seems clear that a factory of 10,000 tons output of pericarp-oil per year is regarded as the minimum likely to be profitable. This amount of oil would be obtainable under Sumatra conditions from 15,000 acres of plantation. Observation of available crop-records shows that during the month of maximum harvest not more than one-seventh of the total year's crop has to be handled, and the month of minimum

harvest accounts for one-twentieth or less of the year's crop. For a factory of the size under discussion, therefore, provision would have to be made for the handling of 6,000 tons of fruit in the busiest month, assuming a commercial extraction of 25% oil to fruit. At the same time, the machinery would have to be in units capable of handling economically harvests of not more than 2,000 tons in the slackest months. The daily capacity of the factory, assuming that work is carried on for 25 days per month, would have to be elastic enough to cope with amounts varying from 240 tons to 80 tons of fruit per day.

Once the capacity of the factory has been decided upon, it will be necessary to select the processes and methods likely to be most successful. Dutch experience in the East points to the following broad outlines of work as being the best so far known :—

(1) Rail transport of whole bunches to the factory.

(2) Bunch-sterilization without removal from the rail-trucks.

(3) Double-pressing (whole fruit and partly exhausted fibre) in hydraulic presses.

(4) Possible application of horizontal Archimedean screw presses as a substitute for hydraulic presses.

(5) Benzene extraction for complete exhaustion of residual oil.

(6) Centrifugal cracking of nuts.

(7) Scum-presses as adjuncts to steam-vats for purification of expressed oil.

(8) Bulk transport of oil to the port, bulk storage at the port, and bulk shipment in tank-steamers.

Some idea of the cost of a fully equipped oil-palm factory of 10,000 tons capacity can be obtained in Sumatra, although in general it is difficult to persuade owners to give exact figures. It was stated that the cost of the new factory at Nijkerk of this capacity was 2,000,000 gulders (£166,666), which would mean a capital outlay of 200 gulders (£17) per ton annual out put. Marihat factory, of the same capacity and similar arrangement, was stated by Krupp's engineers to have cost 1,000,000 gulders, and it was further stated that this figure included all adjuncts such as office, chemical laboratory, railway, storerooms and workshop.

The construction engineers did not know the sum charged by Krupp, and the owners naturally would not make the figures public. The Nijkerk figure quoted above is certainly far above the truth, and it is doubtful whether the Marihat figure is not also exaggerated. A sugar factory is of greater complexity than an oil palm one, and the capital outlay ranges from about £10 per ton output of sugar to £15.

Barnes * estimates the cost of a factory to handle 3,000 tons of fruit per year at £10,000. If an extraction of 25% be assumed, this figure would work out at 1,200 tons of pericarp-oil, and would represent a capital outlay of £9 per ton of oil produced in a year, a figure almost identical with that quoted for Marihat.

It seems fairly certain that the cost of a thoroughly equipped factory will be somewhere in the neighbourhood of £8 to £10 capital expenditure per ton of oil output. Accurate estimates can be obtained only by submitting specifications of the machinery needed to a firm of engineers experienced in the work and obtaining from them a detailed estimate. The estimate should include rail (tram) transport, actual factory, offices, storerooms, workshop, and last but not least a thoroughly up-to-date chemical laboratory for controlling the efficiency of factory and plantation. The cost of a 10,000 ton factory on these lines will not be far short of £100,000.

A few words on the question of a control-laboratory are necessary. On practically every step in the manufacture of palm-oil there is a complete dearth of accurate information. The relative merits of pressing and centrifugalling, the efficiency of different methods of purifying oil, the effect of varying times of boiling the fruit, control of the furnaces, are a few of the points which need study and on which private firms who have worked out new methods are hardly likely to publish free information. But most important of all is the fact that no progress can possibly be expected from an industry which is conducted on crude empirical lines. Past history of cane-sugar and quinine, to take two crops which are decadent or absent in British Colonies and thriving in foreign ones, should be sufficient to prove this point.

Possibilities in the Gold Coast.

The ultimate aim of the visit to the East which is dealt with in this report was the obtaining of information from a consideration of which the Government would be able to formulate a definite policy with regard to the future of the oil-palm industry. It does not seem likely, or even possible, that a sporadic and irregular village industry, however large it may be, can stand up against an organised and scientifically controlled system of capitalised plantations and factories. Quinine, cane-sugar, tea and rubber are examples of forest crops which, almost within the life-history of living men, have been converted into organised plantation and factory industries.

Tropical crops which have persisted very largely as peasant industries, and which appear to be able to compete in that form against a more complex system of plantations or factories, are cacao

* "Chemical Investigations into the Products of the oil-palm": Department of Agriculture, Nigeria, 1924.

and coconuts. In the latter case the explanation probably is that the oil is an article of universal household use : the surplus goes to the markets and finds a ready sale at cheaper prices than most capitalised factories can face. In the case of cacao, a product of limited dimensions which needs practically no process of manufacture or treatment before export has been changed from a plantation product to a peasant one. The complicated processes of manufacture have been centralised in Europe, and the mere cultivation of the plant and reaping of the beans have not demanded enough skill to oust the small inefficient peasant holding.

The real danger to the West African oil-palm industry is probably not the disappearance of its cultivation there. The use of the oil is as firmly established there as is that of coconut oil in other tropical countries. A more likely danger is the loss of the export trade, which means loss of wealth and loss of revenue. As the uses of palm-oil become more specialized and the market expands, the demands for oils of standard, guaranteed quality are bound to increase. And those demands are not likely to be adequately met by an inefficient and irregular forest industry. A large selling combine of plantation companies in the East, such as are in operation for sugar and quinine at the present moment in Java, would be very likely to force and control the European markets.

The cost of capitalizing an efficient system of oil-palm factories in West Africa is too high to permit a Government to embark upon the task, even if it were regarded as advisable. For this reason is seems certain that private capital must be enlisted. In 1920 the world's production of palm-oil was estimated to be about 130,000 tons,* an amount which the Sumatra plantations are within a measurable distance of supplying ; the capital cost of factories with this output would be about £1,300,000. It is extremely doubtful whether capital would be invested in costly factories if the sole source of the oil palm fruit was the forest, or even if the palm was cultivated on small holdings outside of the control of the factory. Small holdings of sugar-cane, of tea, of rubber have thriven by selling their produce to factories, but this produce has always been merely supplementary to that grown on lands owned and worked by the factory. No cases have been placed on record of highly capitalised factories being regularly and stably supported from independent small holdings in the Tropics, with the possible exception of cotton.

A complicating factor in West Africa is the irregularity in type, age, height and distribution of the existing oil palms. Whether the cost of improving the existing groves will be less than that of establishing new plantations is doubtful. Certainly such an improved grove is very unlikely to attain to the standard of a systematic plantation so far as yield is concerned.

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*Bulletin of Imperial Institute, Vol. XVIII., p. 213.

When everything is considered, it would seem quickest and best to devise some system whereby European enterprise would be tempted to invest capital in efficient factories in West Africa. It is unlikely that this could be done unless a reasonable security of tenure were granted over a nucleus of land of large enough area to render the factory moderately independent.

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Deputy Director of Agriculture.

BULLETIN No. 9.

Department of Agriculture,

Gold Coast.

NOTES ON A VISIT TO THE NETHERLANDS INDIES AND THE FEDERATED MALAY STATES.

PART II.—SUGAR, SNOW RUBBER, CINCHONA, NIPA PALM, BUDDING AND GRAFTING.

BY

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GOLD COAST.

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CONTENTS.

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As in the case of the investigations into the new oil palm indust y of Malaya and Sumatra described in Bulletin No. 8 of this series, the observations recorded in the present Bulletin would not have been possible but for the willing support given to the writer by the Government Authorities in the Netherlands Indies and Malaya. In all three countries visited, information and help were given generously and willingly, and it was thus possible to obtain a large amount of information in the period of time available.

It is hardly possible to acknowledge the source of each item of information here, and all that can be done is to state frankly that this Bulletin contains knowledge amassed by persons other than the writer, and that the writer can only claim to have observed, noted and described the information given so liberally.

For the opportunities given for the study of the subjects in this Bulletin a special debt of gratitude is owing to the following gentlemen :— Lieut.-Colonel Gage, of the Linnaean Society, Mr. W. N. Sands of the Department of Agriculture, Malaya, and Dr. Kerbosch of the Government Cinchona Plantations, Java, in the case of the quinine industry ; Dr. Cramer of the Department of Agriculture, Netherlands Indies, Mr. Gallagher and Mr. Grantham of the Holland America Plantations Company of Sumatra and Major Gough of Kadjang Estate, Malaya, for the information on which the notes on budding and grafting are based, and in the case of Mr. Grantham for an opportunity of observing the 'Snow' rubber process : and Mr. Eaton and Mr. Grist of the Department of Agriculture, Malaya, and Commander McGilligan for help and courtesy in connection with the newly-founded plantation of Nipa palms.

Free use has been made of Mr. Sands' article "The Cinchona (Quinine) Industry in Java" (Malayan Agricultural Journal, March, 1922) and of Colonel Gage's article "On the use of Cinchona Alkaloids in the Treatment of Malaria" (Transactions of Royal Society of Tropical Medicine and Hygiene, Vol. XVIII, No. 7, 1925, pp. 345–352). Information concerning the Java Sugar Industry was obtained through the kindness and courtesy of the staff of Pasoeroean Experiment Station.

AGRICULTURAL RESEARCH IN THE EAST.

In Part I of these Notes (Bulletin No. 8 of the Department of Agriculture), the establishment by the Dutch and English of a plantation industry of oil palms was described at length. As in the case of the tea, rubber and quinine industries, all of which have been converted into systematic plantation enterprises within the memory of living men, the success of the new oil-palm industry will depend upon the efforts of planters capable of enlisting and understanding the work of research officers. Without close co-operation between the planter and officers responsible for investigational work it is not possible to build up a stable system of agriculture in any country, and more and more it is being recognised that purely empirical knowledge as opposed to knowledge obtained by deliberate and directed experiment, does not suffice if a permanent and efficient system of agriculture be desired. In other words the planter must be in part a research officer, and the research officer must guide his work in accordance with the needs of the planter.

In no tropical country has an entirely satisfactory connection between planting and research been established, and at the present moment methods differ in each country. In the more primitive countries, where an enlightened planting public is absent, investigational work is entirely dependent upon the efforts of Government. In more advanced countries there is a division of the work; all of the investigations which relate to local peasant crops have to be carried out by the Government, while that work which relates to plantation crops tends more and more to be segregated into the hands of technical specialists who may be employed either by Government or by the planters. In the more advanced countries, technical specialization has tended recently to pass entirely out of the hands of Government into those of research workers provided by the plantations.

The Gold Coast may be taken as typical of the first group. Practically all of the agriculture has up to the present been in the hands of peasant farmers, and all investigational work has been done at the instance of Government. In the West Indies, until quite recently, the initiative in matters of research both for peasant and plantation crops has lain entirely in the hands of Government. In Mauritius until 1912, technical research in connection with the sugar industry was carried out by a Station Agronomique supported by a direct cess on that industry: it is now divided between the chemical employees of the various sugar-factories and the staff of the Government Department of Agriculture.

In Ceylon and the Federated Malay States the dual nature of the research work of the Departments of Agriculture is very evident. On the one hand is the mass of organised work, partly investigational, partly educational, which aims at improvement of the methods of peasant agriculture and which lies entirely in the hands of the Department of Agriculture, although in the case of Ceylon it was inaugurated, and carried on for many years by the unofficial Agricultural and Commercial Society. On the other hand, there is the very specialized technical research work which is concerned with individual crops and which is incessantly stimulated by the demands of the large plantation-interests. This latter branch of work is being increasingly handled by special officers, or staff of officers, provided by direct cesses on the industries concerned, although the methods of directing and controlling the work of these officers differ in different cases.

The organised research schemes now in existence in Ceylon and Malaya are the Rubber Research Scheme of the former and the Rubber Research Scheme and the Tea Research Scheme of the latter. These schemes are supported partly by a direct cess on the crop concerned or on the land producing that crop and partly by a contribution from public funds of the Colony. In the case of the Ceylon Scheme, payment of the cess is voluntary, while in Malaya it is levied on all rubber. The staff of each scheme is separate from that of the Department of Agriculture, and is controlled by a committee representing the producers and the Government. On these committees the senior technical officers of the Department of Agriculture are given seats, and the Chairmanship is usually held by the Director of Agriculture, these arrangements being devised to prevent overlapping of investigational work and at the same time to secure the advice of scientific officers of the Department for the Scheme.

Organisation of research in agriculture is carried to higher pitch of efficiency and specialization in Java and Sumatra than in the other countries mentioned. Three main phases of the work are in evidence. The first is the work of the Department of Agriculture, Industries and Commerce, analogous to that of Departments of Agriculture in British tropical countries, but on a far wider and more comprehensive basis.

Secondly, there are organisations, similar to the Research Schemes of Ceylon and Malaya but entirely unofficial, devoted to research in special crops, the best known being AVROS (Experiment Station of the General Association of Rubber Planters of East Coast of Sumatra); the Deli Experiment Station, supported by the powerful and wealthy Deli Tobacco Group of estates of Sumatra; the Tea Experiment Station supported by Java tea estates, and the two Sugar Experiment Stations at Pasoeroean and Cheribon in Java supported by two groups of sugar estates. The third phase, in

some ways more interesting and important than the other two, is the provision made by individual companies for scientific research work. Among these may be mentioned the work of the research division of the staff of Boeneot Rubber Estate (Holland-America Plantation Company) under Mr. Grantham; the work of improving the yields of oil palms and Hevea Rubber carried out by M. Ferrand of the Société Financière Belge, and Dr. Fickendey's work on oil palms and palm oil machinery with the R.C.M.A. (Rubber Cultuur Maatschappij Amsterdam).

It is not possible to deal with each of these activities in detail, and it would be laborious to trace the effect of the great mass of research work on the productiveness of the countries concerned. The work of the research staff and that of the commercial plantations react on one another; investigation is directed and incessantly stimulated by the demands of planters for accurate and up-to-date information, while on the other hand every item of knowledge published by the research staff is eventually absorbed by the planters and incorporated into the ordinary every-day routine of estates. Improvements in the methods of rubber manufacture, stoppage of soil erosion by means of cover crops, the invention and manufacture of new palm-oil machinery, standardisation of quality of sugar and tobacco, the commercial application of rubber-budding, improvement of factory furnaces, improvement of the type of oil palm planted, shortening of the life-period of the sugar-cane to accord with the local laws controlling lease of land, accurate and regular agricultural statistics; these are a few random examples which strike the visitor.

Whether the variety and richness of the investigational work carried on all over Java and Sumatra are merely a phase of the efficiency and progressiveness of the Dutch planters, or whether the efficiency and productiveness of their plantations and factories are the results of the volume of exact information on all agricultural points produced day by day from their research staff, is a minor point. Probably both are true, but the sum-total of result is that standards of efficiency in every phase of life, personal, agricultural or commercial, exist in these countries which are found in no British tropical Colony.

In only two crops, quinine and tobacco, has the Dutch pre-eminence been due to natural advantages of country and climate. Oil palms, sugar, coffee, tea, rice, rubber enjoy no natural advantages which are unobtainable in British Colonies in which these crops are grown. The difference can be attributed only to the difference between the training of the Dutch planter and research-officer and that of the British ones, and the prominent place given to developmental work in the programme of policy of the Dutch Colonial Government. It is a case of empiricism versus directed investigational work, steady continuous progress in efficiency versus happy-go-lucky opportunism.

Industries, or phases of industries, in the Netherlands Indies and Malaya in which outstanding progress has taken place within recent years are numerous, and in making choice of the ones dealt with below no attempt at completeness has been attempted. Those activities which are of interest to the British Tropics have been chosen, and some attempt made to describe them and explain them, but many of equal standard of efficiency have been omitted. The ones dealt with are :—

(a) The Java Sugar Industry

(b) Manufacture of 'Snow' Rubber in Sumatra

(c) Quinine plantations in Java

(d) Recent work on budding and grafting

(e) Nipa-palm cultivation in Malaya.

In each case it will be assumed that the reader has some knowledge of the industry as ordinarily carried on, and only novel points or those of special interest will be mentioned.

THE JAVA SUGAR INDUSTRY.

In 1926 the area of sugar cane in Java was 443,831 acres, the average yield from this area being 45.2 metric tons of cane per acre.

The total crop was therefore 19,970,000 tons of cane from which were extracted and exported 2,300,000 tons of sugar, an average of 5.2 tons of sugar per acre.

The average yields per acre for certain other countries are given as follows :—

Hawaii (1923)	3.6 tons per acre.
Cuba (1923)	1.7 ,, ,, ,,
Queensland (1923)	1.7 ,, ,, ,,
Mauritius (1923)	1.6 ,, ,, ,,
India (1924)	1.0 ,, ,, ,,

The Java crop is handled by 180 factories, who thus crushed an average of 110,000 tons of cane and manufactured 12,800 tons of sugar each in 1926, the reaping season lasting 110 days. The smallest factory controlled an area of 773 acres and the largest 15,963 acres, the largest and smallest weights of cane crushed by factories in the 1926 season being 34,800 tons and 637,000 tons respectively. The least complex factory possessed one pair of crushers and two 3-roller mills, the most complex used two pairs of crushers and four 3-roller mills. The total capital invested in these factories, apart from the plantations, is not far from £35,000,000. The efficiency of the factory work may be gauged from the figure *sugar exported per cent. sugar present in cane* which averaged 84.8 in 1926. The average purity of the white sugar made was 99.62.

These are imposing figures, but their real weight can be realized only by comparing the industry in Java with the same industry in other countries. The chequered career of the industry in Mauritius and the West Indies, British Colonies, during the past half-century is too well-known to need mention, and in these two Colonies the industry is again on the verge of bankruptcy at the moment of writing. In Java on the contrary the total output of sugar has risen steadily and without retrogression from 71,000 acres in 1839 to nearly 450,000 acres in 1926, and during this period the average yield has risen from 1.3 to 5.2 tons per acre. In 1923 the yield per acre in Mauritius was equivalent to that of Java in 1872, and the Queensland yield to that of Java in 1873–1880, while the acre yield in British India in 1924 was equalled by Java in 1851–1855.

The development of this immense industry in Java is a greater triumph than would appear from a mere inspection of figures. The country is dry and, in 1925, only 26,250 acres of cane out of a total of 443,831 (six per cent.) were left unirrigated. The irrigation-water is drawn from the systems used by the villagers for their rice-fields and is thus obtainable only when the land is clear of rice. In many cases, the sugar-estates have found it necessary to instal new and efficient irrigation systems at their own expense to ensure an adequate supply, the villagers benefiting by the improvement during the rice-season.

A severer handicap have been the local laws of land-tenure. Europeans may not buy land outright for agricultural purposes, so that the whole of this immense industry is carried out on hired land. Rent payable to the native is fixed by Government and is fairly high (£3.4 per acre in 1921, £3.10 in 1922 and £3.18 in 1923). A factory cannot in one year plant more than one-third of the fields rented from a native community, and thus each year the crop is harvested from a different field and ratooning is impossible. A lease for a period of 21 years means that each field may be used only seven times in that period. The conversion of the rented rice-fields into sugar-cane fields at the beginning of the cane season, and its reconversion into irrigated rice-fields at the end, are charges borne by the sugar-estates.

The impossibility of growing ratoons (annual cutting of new growth from the original plants) is in itself a handicap. Other countries run to 2, 3, 4 and even more ratoons and the cost of preparation and planting is saved in years subsequent to the first. In addition, the season available for cane cultivation is materially shortened in Java by the exigencies of the rice-season, only 14–16 months being available instead of the normal 16–18. This difficulty has been overcome partly by breeding new varieties of cane of shorter life-period and partly by growing the cane in up-country nurseries for three or four months and then transporting to the fields in the low country. The task of transporting growing cuttings for half-a-million acres at a rate of about 3,000 plants per acre is formidable.

The old Black Cheribon cane finally disappeared from cultivation in Java in 1921. It was replaced first by a seedling variety bred locally (No. 247B) which in 1912 covered 54 per cent. of the total cultivated area. 247B has gradually diminished and the favourites which successively displaced others since are 100

POJ, DI 52 and EK 28: in 1925 these three occupied 12½ per cent., 22½ per cent. and 43½ per cent. of the cultivated area respectively. The yields are interesting :—

TONS PER ACRE OF SUGAR YIELDED—AVERAGES FOR JAVA.

	EK 28.	All varieties including EK 28.
1914	5.78	3.98
5	5.00	3.67
6	5.61	4.32
7	5.88	4.76
8	5.37	4.52
9	4.55	4.01
1920	4.59	4.08
1	4.73	4.32
2	4.90	4.56
3	4.86	4.52

The gradual rise in the general crop is very striking; the figure for 1925 in 5.2 tons per acre.

The other point of interest is the gradual deterioration in yield of each successive new cane, a phenomenon noted in all countries. In this case EK 28 when new gives an enormous yield and gradually declines until in 10 years it is hardly better than the general average, the latter having in the meantime been raised considerably by the gradual spread of EK 28 and other improved types in the country.

Many of these new varieties are bred by the estates. EK 28 and DI 52 for example are from estates while POJ 100 was produced at the Central Experiment Station at Pasoeroean. The work of the Experiment Station stimulates that of the estates, while the keenness of the planters for new information and progress resulted in the first instance in the foundation of the Experiment Station.

Pasoeroean Experiment Station was started by the estates and is supported by a direct cess on every pound of sugar exported by the contributory estates. The same applies to the smaller station at Cheribon, the cess in each case being stated to be about ¾ of one gulder-cent per 100 lbs. of sugar (1 gulder=1/8 English), or about 3/- per ton. Over 160 factories of Middle and East Java contribute to Pasoeroean and the remainder to Cheribon.

The degree of specialization at these Stations is remarkable. At Pasoeroean the research work is carried out by six Divisions :—

1. Direction and Administration
2. Cane breeding and Botany of cane
3. Field studies, plantation-inspection, studies in cultivation and irrigation
4. Geology, Agro-geology, Meteorology and Analyses
5. Engineering work
6. Chemical work

It is not necessary to give the outlines of work in each of these sections, but, as a matter of interest, the subheads of Division 6 are enumerated below.

6. Chemical work.

Studies in clarification, boiling-process, evaporation, exhaustion of molasses ; studies on incrustation of evaporators and other apparatus, analyses of molasses and sugars. Researches on extraction of juice from bagasse, analysis of bagasse and juices during manufacture.

Consulting engineering, visits to factories, supervision of trials in factories.

Chemical control, study of factory results, and of molasses.

Sugar laboratory, inspection and control of optical and chemical apparatus, gauging of density-weighers, weights, balances, glassware.

Laboratory for molasses, limestone, lubricating oils, calorific value of fuel.

Six Europeans are given in the staff-list for Division 6 above.

An activity of great interest which may be seen at Pasoeroean Experiment Station is the calculation of figures for the Mutual Control system. During the reaping season of cane, each factory forwards all figures at the end of each fortnight to the Experiment Station. The figures are grouped roughly in classes such as field figures, mill-figures, evaporation-plant, fuel control, analytical figures, &c., and each class of information is detailed in full. For example sugar lost in fibre, in residual molasses, in filter press cake,

from evaporating plant, unknown losses, sugar present in the cane entering the factory, sugar present in the juice from the mills, are all figures derived from factory weighings and measurements combined with those obtained by systematic analysis, and from them can be compiled a fortnightly balance-sheet of the total sugar reaped and the total shipped. These sheets are of great extent and complexity, and in 1925 were sent in fortnightly from 180 factories.

Speed being essential in carrying out these calculations and in publishing the results for the information of all factories, all calculations are carried out on calculating machines worked from the electric lighting system of the Station. By means of a careful arrangement of factory-figures on a form of standard pattern, and the use of fifty electric multipliers and fifty dividers, the final summary for each fortnight is prepared, published and sent to contributing estates within the next fortnight. The figures in these summaries are given with the names of the estates to which they belong, and it speaks well for the broad, enterprising spirit of the Dutch that these summaries are sent to other sugar-producing countries. The stimulus that the system imparts to the work of all factories is powerful, and no improvement takes place in one factory that is not known to all in a fortnight.

This description would hardly be complete without some reference to the system of marketing the sugar which is in operation in Java. Selling lies in the hands of a small committee appointed by the estates. Forecasts of the crop in Java and elsewhere, trends of the market, boat arrangements and other matters vital to the industry, but lying beyond the scope of individual Estate Superintendents fall within the scope of this committee. Owing to the standardisation and efficiency of the methods of manufacture, the committee can go into the market months ahead of the crop and quote with absolute confidence the amount and quality of each grade and make selling contracts to the best advantage. Sales are effected of Java sugar quite irrespective of the estate from which the sugar is derived, and the proceeds of each individual sale is divided up among estates proportionately to their quota of sugar handled by the ' Cartel ' committee. The system does not appear to result in any undue raising of the price in the world's markets. By efficient methods of cultivation, manufacture and marketing the Java planters can make profits at prices which result in the bankruptcy of the industry in British Colonies.

MANUFACTURE OF 'SNOW' RUBBER IN SUMATRA.

The ordinary method of preparing rubber on plantations consists of collecting the latex or 'milk' tapped from the trees and separating the rubber from the latex by coagulation. Latex consists of an intimate intermixture of extremely fine particles of rubber with a serum or sap composed of water in which are dissolved other substances, *e.g.* salts and albuminoids. By adding acetic or formic acid to the latex the emulsion is broken up and the rubber-particles collect together on the surface of the serum as a 'coagulum'.

Subsequent operations are aimed at removal from this coagulum of all foreign matters enclosed in the coagulum during the process of coagulation. This is effected by rolling and washing. The thick coagulum is passed and repassed between polished steel rollers until it is converted into an extremely thin band of rubber, washing being carried out simultaneously by means of fine jets or sprays of water which play on the rubber as it passes through the rollers. The band is rolled up into thick folds and the rolling repeated, the process being carried on until practically all salts, coagulating acid, albuminoids, etc., are washed away.

The pure 'plantation-crêpe' rubber resulting from this rolling and washing may then be dried and packed, or smoked to a rich amber colour and then packed. In the one case we get standard crêpe, in the other smoked sheet, and in each case the final process is laborious and slow. Drying of rubber is very slow as it takes many days at a fairly high, controlled temperature to drive the last traces of moisture from the interior of a sheet. Similarly the thorough curing or colouring of sheet-rubber by smoke takes may days.

These two processes are in operation in Ceylon, Malaya and Sumatra, but recently a process has been patented which differs fundamentally from them and which bids fair to revolutionize the whole system of preparing rubber. It is in operation on Boenoet Estate in the East Coast Governorship of Sumatra, and is known as 'centrifugal rubber' or 'snow rubber'. The patent is held by the Holland-America Plantations Maatschappij, and the product appears to go to the American market alone.

By this process, 'whole rubber' is made, that is there is no attempt to remove salts, albuminoids, etc. The collected latex is bulked in tank railway waggons and ammonia gas is bubbled through it from steel pressure cylinders.

The ammonia acts as an anti-coagulant, and the latex will keep uncoagulated until it reaches the factory. As a matter of actual fact, ammonified latex will keep for several months unaltered. At the factory, the waggons are discharged by compressed air, the latex being forced into overhead tanks in the factory, from which it can be distributed to the centrifugal discs.

The centrifugal discs are of polished steel, about 18–20 inches in diameter and half-an-inch thick ; they are about the size and shape of a large gramophone record, and are driven by electric motors at a speed of 2,000 to 2,500 revolutions per minute, in the same fashion as are electric fans. The whole machine (disc, spindle and motor) is small enough to be lifted out by one man when repairs or cleanings are necessary.

The drying-chamber is circular and is dome-shaped, the disc being set in the centre of the dome in the fashion of an electric fan on a ceiling. The diameter of a chamber is about 45 feet and the height about the same. The wall of the chamber is double cased so as to admit of hot air between the two casings, and when the unit is in operation a rapid current of hot air is drawn through the inter-mural space. The temperature of the air-current is 500° F in the upper part of the space and 200° F in the lower part, so that the chamber is subjected to a fairly high degree of heat.

The process is as follows. Latex is run down the spindle on to the upper surface of the rotating disc, and is spun off centrifugally in the form of a fine, mist-like spray. As the fine particles settle slowly down through the hot air of the chamber water is driven off, and each particle arrives at the floor thoroughly dried. The particles are of rubber mixed with albuminoids and salts and as the 'snow' of particles fills the floor-trays the latter are drawn out of the chamber and emptied. The 'snow' rubber is then pressed in a screwpress into blocks of 200 pounds each, sewn up in jute-cloth and shipped.

An idea of the fineness of the 'snow' particles, and also some notion of the efficiency with which the operations are controlled by the research staff of the estate, may be obtained by noting that the diameters of the particles spun off from the disc have been measured and have been found to range from 2 mus to 300 mus (.0005 to .075 of an inch). This irregularity causes some 'caking', and trials are being made to overcome this either by patterning or modifying the shape of the discs.

Boenoet Factory works day and night, and the seven discs which are employed turn out 3,000,000 pounds of dried rubber per month. One disc therefore can turn out 14,286 pounds of dried rubber (6½ tons) per day. The plantation belonging to the factory is 42,000 acres in area but a large amount of latex is bought from neighbouring estates, so that the total area served is between 60,000 and 70,000 acres. The process is stated to be so cheap that a high price is paid for the latex, and it is more profitable for a plantation to sell its latex to Boenoet than to manufacture it into crêpe or smoked rubber.

It is perhaps too early to decide definitely as to the merits or shortcomings of this new process but everything seems to point to the probable replacement of the crêpe and smoked sheet methods by this or some similar process. The change is so fundamental and revolutionary that it could hardly have succeeded unless it brought great profits and advantages with it. The chief advantages appear to be a saving of factory-space and greatly increased speed of manufacture, and both of these must imply great saving in cost of manufacture. The whole of the immense area of floor-space used in the old methods for coagulating-tanks and dishes, for rolling-machines, and the huge drying-houses or smoke-chambers are saved, and instead we have the modest area and volume required for the centrifugal drying-chambers. It is interesting to note that no attempt has been observed to run the rollers in an ordinary crêpe factory in tandem : the rubber is fed to each roller by hand, pulled through by hand, re-blocked by hand and re-rolled by hand each successive time. The cost of this handling is not included in the comparison in this paragraph or the next.

Exact figures were not obtained for the consumption of horsepower involved in running a centrifugal disc, but for a disc of 24″ diameter and ½ inch thickness rotating at 2,500 revolutions per minute the theoretical horsepower needed is 8. Assuming that a rubber-roller can handle 200 acres, some 300 rollers would be needed to handle the 67,000 acres of Boenoet, and the consumption of horsepower per roller is about 5.

There is a conflict of popular opinion regarding the effect of the presence of albuminoids and salts in rubber manufactured by the centrifugal process. On the one hand there is an added weight of 2½ to 7% of these impurities and apparently the buyers have not yet taken this into account in their prices for " snow " rubber, so this may be regarded as profit. On the other hand it is claimed by some that the presence of these impurities improves the vulcanizing properties of the rubber, and by others that it harms the quality of the final vulcanized product.

The fact remains that 'snow' rubber sells readily in the American market, so that the impurities must either be regarded as beneficial or must be capable of ready removal during the ordinary processes of maceration which precede the manufacture of trade articles such as tyres, &c., &c.

An additional saving is effected by the use of jute sacking instead of the three-ply wooden cases ordinarily used for shipping crêpe or smoked sheet.

Although three-ply wood is made in Java from local forest trees, Boenoet factory apparently finds it cheaper to ship its rubber from Sumatra in jute.

QUININE INDUSTRY IN JAVA.

Before proceeding to a description of the main points of interest of the Cinchona (Quinine) industry of Java, it may be wise to state that it is extremely unlikely that this crop can ever be grown profitably in the Gold Coast. More than perhaps any other tropical crop, cinchona needs very special conditions of elevation, rainfall and soil before it can be grown, conditions which occur in no part of the Gold Coast, and the limits within which these conditions can vary are extremely narrow. In addition, the amazing blend of high technical skill, foresight and patience attained by the Dutch in their establishment of this industry has no parallel in the British Tropics ; skill which is evident in the plantation, the laboratory, the selection nursery and the markets, and which has resulted in an efficient and complete control of the industry.

From 90 to 95 per cent of the world's supply of quinine comes from Java. The average exports from the Netherlands Indies per year for the period 1916 to 1920 were as follows :—

Quinine Sulphate ..	686,042 lbs.	£1,100,000
Bark	10,350,482 "	£340,000

The industry failed in Mauritius, has disappeared from Ceylon, and in India is restricted to the production by Government of a portion of the supply needed by the Medical Department of the country.

The production of quinine differs from most tropical agricultural industries in one important respect, and this difference appears to be the factor which controls the questions of production and marketing. In the cases of rubber, tea, sugar, cacao, in fact in practically every plantation-crop, we have a product required by the peoples of temperate climates. The tropics are used to grow a crop which is sold to the wealthier, more progressive temperate regions. Quinine is fundamentally different. It is needed for tropical races, either too poor to buy it or too badly organised to profit by it. Thus the saleable amount is limited, the price is limited, and under ordinary conditions the normal demand comes from a few Europeans in the Tropics and Temperate zones or a few Northern Governments endeavouring to distribute supplies among ignorant or unprogressive tropical races.

The case can be made clear by considering one country. A consumption of 5 grains per day means a total of 4 lbs. per year. For India alone this would mean 1,200,000,000 lbs. per year, or more than 100 times the total production of Java. That the estimate is

not fantastic can be proved by remembering that the consumption of tea, a luxury, is over 5 lbs. per head per year in British temperate countries. Were malaria a disease of temperate climates, there is little doubt that the consumption per capita of quinine would at least equal that of tea.

The limited market and its slow rate of expansion, the small quantity of quinine obtainable per acre, the narrow limits of elevation, rainfall, temperature and type of soil within which the plant succeeds all combine to make cinchona a precarious crop. Hard words have been said about the Dutch and their monopoly of the quinine-trade, but actually they have saved a necessary industry from complete extinction and have done this by a combination of foresight, business ability and skilled technical work. The agreement made in 1913 between planters and sellers and renewed with an important modification 5 years later is of interest in this connection.

In the first agreement the growers pledged themselves to sell to the manufacturers' combine only and the combine agreed to fix a minimum price for bark but to accept obligation for a definite amount of bark only. In the second agreement provision was made for a division of profits between grower and buyer when the selling-price of quinine exceeded a certain figure. Examination of the export-figures shews that every year the amount of quinine sulphate shipped increases relatively to the amount of bark exported and that there has been a regularly increasing saving of freight on useless waste, and the producers naturally wish to share in the profits resulting from this saving :—

Quinine Sulphate Exported.
Kilograms. *

Year.	As Alkaloid.	In bark.	Ratio.
1916	115,175	495,508	1:4.3
1917	120,978	164,126	1:1.2
1918	252,636	146,370	1: .6
1919	640,328	325,248	1: .5
1920	418,861	278,175	1: .6

The local - factories do not allow visitors to enter, and apparently the same prohibition exists in London laboratories. While extraction of any alkaloid is troublesome, it should not present unusual difficulty in the case of quinine.

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*One kilogram = 2¼ pounds.

Sands gives the annual average production per acre on well managed plantations as follows :—

Year.	Yield of Dry Bark—Pounds.	Quinine as Quinine Sulphate.
4th (1st of production)	125	6 lbs. (@5 %)
5th (2nd „ „)	250	16 „ („ 6¼ „)
6th (3rd „ „)	375	26 „ („ 7 „)
7th (4th „ „)	500	37 „ („ 5 „)
8th (5th „ „)	630	50 „ („ 8 „)

Subsequent annual yields remain at about 650 pounds of bark per acre. Taking poorer plantations into account, the average yield is given as 550 pounds of bark (containing 6% of quinine sulphate) or 33 pounds quinine sulphate per acre.

It seems fairly clear that the plantation-costs of growing quinine are high per pound of product. In 8 years an acre produces 135 pounds, and the trees are destroyed in that period and fresh plantations are necessary in new soil. Transport charges are high, involving payment of freight on 94 pounds of waste for every 6 pounds of alkaloid produced, and finally the extraction of the pure alkaloid is troublesome and needs skilful chemical control. It is open to question if the industry could possibly be made profitable even under the most favourable conditions, unless the market is under some sort of control either by Government or by combined action of the producers.

To turn now to purely agricultural matters. The optimum elevation in Java at which the high yielding *Ledgeriana* variety of cinchona will grow is 4,500 to 5,000 feet and the optimum rainfall 100 to 200 inches per year. In Malaya, cinchona grown at 1,500 feet is stated to have contained so little quinine as to be valueless commercially. In Java at 3,200 feet the trees grew rapidly but were very short-lived. Above 6,000 growth was too slow, and damage from frost also became a serious hindrance. By the use of the hardy *succirubra* species as stock and the more delicate *Ledgeriana* as budded scion the Dutch have extended the profitable limits of cultivation to the range 3,500 to 6,000 feet.

At the present time, practically all the cinchona in Java is *Ledgeriana* budded on *succirubra*. In 1925 there were 2,000,000 budded plants in the nurseries at Tjinjiroean Estate alone, and in 1926 the number of budded plants in the fields of this estate was given as 37,000,000. Anyone familiar with the difficulty of budding or grafting will realise the magnitude of the task represented by these figures, and an idea of the efficiency with which it is done can be gained by noting that a trained nurseryman on this estate buds 500 plants per day with an average success of 90%.

The task of budding is perpetually recurrent. The trees are set out at an average of 4 x 3 feet, or 3,630 per acre, and with necessary 'supplies' an allowance of 4,000 per acre is necessary. Uprooting of the trees for preparation of quinine begins in the 4th year and is continued progressively as the trees increase in size until the land is clear. The period of time which elapses from the date of planting to the complete clearance of the land varies from 15 to 30 years, i.e., the productive life of a good plantation varies from 11 to 26 years. The capital cost from clearing of forest land to 1st year of bearing (4th year) varies from £8.15 to £12.7 per acre, plus an upkeep charge of £1.15 per acre per year.

The method of budding used is interesting. A T-cut is made in the bark of the *succirubra* stock, as though for ordinary budding. A cutting of young wood of *Ledgeriana*, some 4 inches long, is made and after trimming is thrust into the T-cut, and the joint waxed. It is a combination of T-budding and grafting.

It may be well to mention here, for the information of those not familiar with plant-breeding, that the mere operation of budding or grafting does not effect any improvement of type or increase of yield. All that it does is to ensure that the character of the plant from which the bud or graft is derived is transmitted unchanged to the new plant, just as it is in the case of a cutting. Seedlings may be crosses or hybrids, whereas a cutting, a graft or a bud must be true to its parent. A grafted or budded plant benefits in robustness because the bud is inserted into a stock selected for its vigour or resistance to disease. In the last section of this Bulletin, some description is given of certain secondary effects on the plant of the processes of budding and grafting.

The improvement in yield of quinine which has been effected in *Ledgeriana* in Java appears to range round about 3 to 3½%, that is it has risen from the range 6–8 to the range 9–11. The improvement is doubtless progressive since buddings are made only from those trees with a high percentage of quinine and a large quantity of bark. At Tjinjiroean Estate, individual trees are examined by removing small sections of bark and analysing them in the control laboratory: those giving the best results are reserved as bud-parents. Percentage of alkaloid in bark x circumference of tree x length of stem gives a useful measure of comparison.

Four commoner alkaloids occur in cinchona-bark. These are quinine, quinidine, cinchonine and cinchonidine and in addition there are alkaloids of no value. All four are useful anti-malarial drugs, but quinine and quinidine rank equal as the most efficient, cinchonidine and cinchonine coming after them in efficiency. In order to provide for the possibility of any of the last three coming into greater popular favour than quinine, selection-trials are being carried out in Java which aim at producing types with low quinine content, one of the other alkaloids being made the major constituent.

A line of work of exceptional interest at Tjinjiroean Estate is the effort being made to restore worn out land to a condition resembling virgin forest. Cinchona will not thrive if planted in land already used for the crop, and, in consequence, after a plantation has been reaped it has been necessary to abandon the land and clear new forest. At Tjinjiroean many kinds of trees are being tried and particularly good results have been obtained from certain "wattles" (Acacias) imported from Australia and South Africa. Certain Acacias which thrive at the elevations suited to cinchona have been found to build up a foot to 18 inches of leaf-mould in a very short span of years, and it seems certain that cinchona can return to these lands within 5 to 10 years from the reaping of the last crop. The Acacia-trees are a valuable source of fuel, and in some cases of tanning-bark when felled.

A final point of interest about this industry is the occurrence of *Armillaria mellea*, the fungus which causes "collar-crack" of cacao in the Gold Coast, as a pest on cinchona. Java authorities state that this fungus is cosmopolitan in all parts of the Tropics.

NIPA PALM CULTIVATION.

An unusual crop which presents several points of interest is being grown on an estate on the western coast of the Federated Malay States. Commander McGilligan and some other gentlemen have established an area of 850 acres in Nipa-palm cultivation (*Nipa fruticans*) with the intention of producing industrial alcohol. Many palms, for example oil-palms, coconut-palms, Caryota urens and Borassus are tapped for sugar or alcohol, but the Nipa is of unusual interest because of its habitat and its method of growth.

The Nipa grows in standing water. It is slowly blocking many of the rivers and canals on the lowlying coast of Malaya. It will apparently grow in brackish water, although the limit of salinity has not been recorded. The conditions under which it occurs in Malaya are apparently similar to those necessary for mangroves, and it is reasonable to assume that it would thrive near the swampy river mouths and deltas of the Gold Coast.

The palm is trunkless, the stem being of the nature of a corm, akin to that of the banana, and ' suckers ' or offsets are thrown up throughout the life of the palm. In consequence, a young growing individual soon produces a thick clump of leaves. There seems to be a tendency to produce these suckers in such a way as to result in groups of four, the original corm sending up three surrounding offshoots.

Male and female flowers occur on the same palm, but the male and female inflorescences are separate. The mature female fruiting stalk consists of an axis, some three or four feet long, at the free end of which is the spherical mass of fruit. Before tapping-operations begin, the axis is bent to and fro so as to stimulate an increased flow of sap from the stem to the fruit ; the injury to the tissues and the partial severing or closing of the conducting-vessels of the axis provoke a response and the flow of sap is more rapid. The young head of fruit is then cut off and the sap flowing from the severed end of the axis is collected ; on successive days thin slices are cut off the end of the axis in order to open up blocked conducting-vessels and renew the flow. In most cases, this retapping is done twice a day, but on the estate under consideration one tapping, in the morning, has been found sufficient.

A simple but ingenious method of planting has been adopted on this estate in order to overcome the difficulty and expense of carrying out tapping operations in a swamp ; large straight drains have been dug through the swamp, these drains being set 18 feet apart. In the case under consideration the permanent water-table

has been lowered to a depth of 3 to 4 feet below the surface of the land, and ledges have been cut in these drains just at the surface of the water-table. The palms are set on these ledges, which are placed at intervals of 12 feet along the drains, so that the palms in the beginning are 12′ x 18′ planting distance or 212 per acre. Suckering is so rapid that the palms form practically a continuous hedge along the drain in the course of five years.

The estimate of yield is 1,000 gallons of alcohol per acre, this being based on the assumption that each clump will have two tappable spathes during the whole year. The local price, in Malaya, of industrial alcohol is $ 1.20 (2s. 9d.) per gallon. If the estimate be correct, the gross return per acre would be £137 10s.

The plantation is of great interest. The unusual nature of the crop, the special means of overcoming the inconveniences which follow the habits of the plant, the fact that it is probably the first European enterprise of the kind, and the possibility of rendering productive those swamps which have hitherto been both useless and unhealthy, all these have directed attention to the enterprise.

The capital charges of establishing the plantation are probably high, and the tapping, fermenting and distilling operations will be costly, so that the initiators will have to overcome many difficulties before they attain success.

RECENT WORK ON BUDDING AND GRAFTING.

There are three crops on the Gold Coast the flowers of which present certain structural or other difficulties in the matter of procuring pure seed of known parentage for selection work. The cacao-flower, with its stamens bent back and hooded by the sac-like bases of the petals, has the appearance of being specialized for cross-pollination, but this conclusion is doubtful in view of the fact that the pollen is adhesive and its transfer is apparently dependent upon insects. Probably a few flowers do become self-fertilised and the greater majority crossed, but these and other points concerning the cacao flower have not yet been studied satisfactorily in any part of the world. A very small proportion of the total number of flowers produced by the cacao plant come to maturity normally, so that trials aimed at elucidating these problems are extremely laborious.

In the case of Cola, a crop rarely grown by Europeans, very little exact information is available. The flowers are of two kinds, male and female, and casual observation shows that the tree may be unisexual or bisexual. In the case of bisexual trees or inflorescences, the numerical proportion of male to female flowers may vary enormously, from those almost purely male to those almost purely female. Probably, also, these numerical proportions vary in the same tree for different years and ages, as they almost certainly do in oil-palms, nutmegs and papaws. Further points of interest in the flower and fruit of the Cola are the facts that what is popularly assumed to be a pod is really one section of a 5-chambered ovary, five ' pods ' springing from one flower, and that the two types of seed, pink and white, may occur not only on the same tree but on the same inflorescence, and even together in one compartment of the same ovary.

The flower of Hevea is very small, and it is not easy to control its pollination. For this and other reasons the ordinary method adopted for securing pure strains of the plant is to graft or bud. In only one case in the East was an attempt observed to supplement budding and grafting by deliberate crossing or selfing the flower. Mr. Ferrand, Scientific Adviser to the Société Financière Belge of Sumatra, is trying to breed pure seed of known parentage so as to obtain types of Hevea combining the desirable characteristics of their parents.

Apart from any physical pecularity of the flower, the sexual method of producing and sustaining new types of a perennial plant is laborious and slow. An individual cacao-tree, for example, selected as a desirable parent on account of its high yield, may itself be a cross, in fact would almost certainly be a cross, and its ancestors similarly are unlikely to have been all of a desirable type from the point of view of yield. For this reason two generations of deliberate, artificial pollination would be necessary, the first to ascertain the degree of mixture of the parents, the second to secure pure strains of those individuals among those progeny of the first generation which have desirable characteristics. Each generation of this work would take from 3 to 6 years in the case of cacao.

Cuttings, Budding and Grafting.–One-stemmed, unbranched plants such as oil-palms cannot be propagated by any but sexual means, and the task of obtaining good types is slow. Dicotyledonous plants, such as rubber, cacao, cola, cinchona, coffee, kapok, cloves, etc., may, on the other hand be propagated by cuttings, and as these cuttings are actual parts of the parent's body, produced by normal growth and independent of sex, they give rise to plants of characteristics identical with those of the parent. One generation therefore is saved, and in addition a cutting produces a mature plant in a shorter period than does a seed. Both cacao and rubber, however, are difficult to rear as cuttings so that some surer and more profitable method must be sought.

The insertion of a cutting, or, what amounts to the same thing, of a vegetative bud, into the stem of another plant instead of into the ground, is what is known as 'grafting' or 'budding'. The method has been used for centuries in temperate climates, notably in the case of citrus fruits and of fruits of the rose order (apples, pears, peaches, etc., etc.). It has the advantages of certainty, since the budded plant is identical with the parent from which the bud or cutting was drawn, of rapidity, since the young bud or shoot has the advantage of using already established roots, and of increased hardiness, since the roots of a resistant, vigorous plant can be selected as the stock. Contrary to what is popularly believed, it is not possible to obtain a 'cross' or a 'hybrid' by budding or grafting: the method is used because it is independent of sexual phenomena, and so produces progeny true to type, in other words because it does *not* produce hybrids or crosses.

In the Gold Coast, the yield of individual cacao-trees have been recorded for many years past on various Agricultural Experiment Stations, and at the present moment there are trees with consistently high yields the records of which are available. Some of these trees have yields of more than 20 pounds of cured cacao, as compared with a mean yield of half-a-pound to two pounds in the case of ordinarily good trees in a good plantation. Similar information is available at some stations with regard to Hevea rubber, a crop

which should be of importance to the Gold Coast, and at others the yields of individual Cola trees have been recorded. For these three crops, and for coffee, budding or grafting is probably the only method of segregating high-yielding types rapidly and efficiently.

Budding of Rubber.—The previous section makes it clear that neither from cuttings nor from a bud or graft is it ordinarily possible to obtain a new type of plant. The methods are of use only for propagating unchanged a type which has been either chosen or developed by other methods. In other words, the really important part of the work is the preliminary selection of a desirable type and the technique of budding or grafting, while necessary, is a comparatively minor question. In practically every case in agriculture, the choice of type would be based on yield, and the greater yield may be the result of one definite character inherent in the plant, or it may be a secondary characteristic dependent upon some pecularity, such as resistance to drought or to excessive moisture, resistance to a disease, or a chance coincidence between the periodicity of the crop and the distribution of rainfall. As an instance in point, it should be possible to increase the yield of cola by setting out a field of budded entirely female plants with an intermixture of the necessary number, say 5% of budded, entirely male types.

In Malaya, Java and Sumatra, four examples were observed of selection of Hevea rubber on a large scale and the propagation of chosen types by means of budding. These were the work at AVROS Experiment Station, Medan, under Dr. de Jong; at Kadjang Estate, Malaya, under Major Gough; at Boenoet Estate, Sumatra, under Mr. Grantham and at Buitenzorg, Java, under Dr. Cramer. In each of these cases the work is ahead of anything observed in Ceylon up to 1924, and it is more than probable that work of the kind witnessed will result in yields of rubber hitherto regarded as impossible.

Boenoet Estate.—Boenoet is the largest rubber-estate in Sumatra, its area under this crop being about 42,000 acres. It is worked in ten field divisions, each with its Superintendent: the road-system is 260 miles in length, and the estate railway system 100 miles. The staff is served by a modern hospital of 1,000 beds. In order to carry on the work of this immense undertaking the staff is organised under three heads, Field, Factory and Research. It is unusual and pleasant to find a commercial plantation possessing a Research Division ranking equal with Field and Factory, and the example might be followed with advantage in British Colonies and by British Companies. Between the years 1923 and 1925, the average yield over the whole of this property has risen from 325 to 480 pounds of cured rubber per acre, the average for Ceylon, Malaya and Sumatra being usually about 350 pounds.

The work of the Research Division on the field side includes comparative manurial trials, bark-renewal experiments, comparison of different systems of tapping, rubber-marcotting as control for budding trials, rubber seed selection as supplementary to budding, and rubber-budding on a large scale. In 1926 there were 5,000 acres of budded rubber on the estate, and budded trees are now in the third generation, that is the following stages have been passed :—

1. Original selection of bud-parents.
2. Planting of first budded plants from 1.
3. Selection of best of first budded plants as parents, from 2.
4. Planting of budded trees from 3.
5. Selection of best trees in 4.
6. Planting budded trees resulting from 5.

On certain fields classed under 6, the yield is estimated at 1,000 pounds of cured rubber per acre, and with reasonable confidence a yield of 1,500 pounds within the next 5 years is expected. Certain of the select trees give 20 to 50 pounds of dry rubber each: one actually observed has a yield of 26 pounds, and as the diameter is about 12 inches the high yield is in no way traceable to any abnormal length of tapping-cut. Assuming the low number of 50 trees per acre and a yield of 400 pounds per acre, the mean yield of rubber on a good plantation would be 8 pounds per tree. On the average plantation it is about 3 to 5 pounds.

For purposes of selection, the estate is one vast experimental station. Following are the outlines of work :—

(a) Individual tapping of trees, and records of yields.
(b) Choice of highest yielding individuals as bud-mothers.
(c) Removal of low-yielding individuals from the fields.
(d) Filling vacancies with select, budded types.
(e) Establishment of new fields with select, budded types.

Removal of bearing-trees is done on the joint decision of the Research and Field Divisions, all low-yielding trees being marked by the former first ; after inspection, the Field Superintendent decides which of the marked trees can be immediately removed without damage to the remaining trees and on his decision the Overseers act. Eventually all trees marked by the Research Division are removed.

Kadjang Estate.—Similar work to that performed on a large scale by the Research Division of Boenoet is carried on by Major Gough at Kadjang Estate, Malaya. In the one case it is carried on by a staff provided for the purpose, in the other it is dependent upon the efforts of an individual. Single-handed and without special training, Major Gough has sandwiched a large amount of valuable work on budding between his numerous duties as Superintendent of the estate of which he has charge.

In general outline, the work at Kadjang is the same as that at Boenoet. A target-graph is kept of individual yields of all trees on the property, and low-yielding types are removed at convenience. The work is now in its second generation, that is, fields are now being planted with budded plants obtained from the highest-yielding budded trees. T-budding is used here.

AVROS Experiment Station.—At this station a considerable amount of budwood from selected trees is sold to planters in Sumatra. In 1925, there were sold 78,000 metres (52 miles) of budwood at 1 gulder (1/8) per metre, the proceeds therefore being £6,500. The wood is sold to estates which contribute to the support of AVROS, an association supported by voluntary cess on rubber properties. These sales give some notion of the keenness with which planters seek to obtain rubber of known, proved types. On the average, a metre of bud-wood has 10 buds, so that at 50% success in budding the amount sold would plant up about 6,000 acres.

A point of interest in the work here is the method by which the large demand can be filled for wood of one clone. The original mother-tree still exists and is used practically entirely for supplying buds for the establishment of a field of budded plants on the Station. These young plants, in the course of 18 to 24 months after budding grow into tall slender stems characteristic of young Hevea, and these stems are cut off 6 or 8 inches above the junction of stock and scion and sold as bud-wood. Shoots which develop from the stock as a result of this cutting-back are removed and a main leading shoot from the scion is encouraged so as to provide budwood for sale in the following year.

The term currently used to describe a group of trees budded from the same bud-mother is " clone ". As will be seen later the characteristics of trees of the same clone are remarkably constant.

Secondary effects of Budding.—The nature of the relation which exists between the two parts of a composite plant (built up by budding or grafting) made up of two individuals must be the cause of much speculation. It is clear that the two plants fuse so that the resulting plant acts as an individual, but there is some evidence to prove that in certain respects they remain distinct. A historic example is the rare phenomenon known as a 'graft hybrid', where tongues of tissue of the stock and the scion interweave up to some considerable distance above and below the point of junction, and growing-buds occasionally spring from a position astride of the two distinct tissues : the growing-buds carry with them in their growth the two kinds of tissue and produce leaves or flowers of the two types. There is no fusion, the two types of tissue uniting but not intermingling, and retaining their own characteristics.

Work done within recent years in the East on budding of Hevea, kapok, coffee and cinchona has shed much light on the reactions between stock and scion, and the information is likely to be of value in the future in the Gold Coast, in connection with cacao, kola, coffee and rubber. Following are some of the pecularities noted with regard to Hevea by workers in Malaya and Sumatra.

(a) The bark of the scion is always smoother, and that of the stock rougher than the bark of an unbudded tree.

(b) Usually the diameter of the stock is disproportionately large in comparison with that of the scion : in extreme cases, this gives rise to an unsightly tree known as ' elephant's foot ', having a huge base and a slender stem.

(c) Scion of budded rubber has a cylindrical stem which does not taper.

(d) The bark of the scion is always considerably harder, and that of the stock much softer, than that of unbudded trees.

The explanation of these four peculiarities is probably that beheading the stock suppresses longitudinal growth and stimulates circumferential expansion, while on the other hand the young scion mounted on a powerful root is forced upward rapidly. Soft bark arises from rapid expansion laterally of the underlying wood, hard bark from rapid longitudinal growth and tardy circumferential growth.

(e) Budded plants give a similar flow of latex at any point of the trunk up to about 9 feet.

(f) Budded trees give latex which coagulates at once in the latex dishes. The morning collectors find a partially solid coagulum in each dish from a budded tree and this does not appear to be caused by acidity nor is it associated with higher content of rubber per volume.

No. (e) is understandable : the diameter being constant up to the point of branching, owing to the absence of tapering in budded rubber, a tapping-cut round one-quarter of the circumference would be of the same length and would sever the same number of latex canals.

No. (f) is not understandable and there is apparently no explanation put forward which is satisfactory.

(g) The habit of a clone is constant, irrespective of the stock on which it is budded. For example a double trunk, an umbrella-shaped head, etc., etc.

(h) Irrespective of the stock on which they are set some clones always give a good union, others always unite badly.

(i) Irrespective of stock, some clones always produce nodules on the tapping-area, a peculiarity which does not occur on the mother-tree or on seedlings of the tree.

(j) Clones which naturally unite well never shew disproportion in size between stock and scion, and are usually good yielders : clones of low yield often give poor union and grow disproportionately on any stock.

(k) Disproportion in size between stock and scion causes bad union and disproportion in diameter ; in Malay a stock is not used if over 9–12 months, but in Sumatra there was some evidence that good union could be effected up to an age of 2 years of the stock, provided that the stock came from a clone of good uniting properties.

In general, it is now realized that, when a high yielding type of Hevea has been obtained, it is necessary to test it on various stocks until the most suitable one has been found.

Dr. Cramer's work at Buitenzorg, Java.—In the British West Indies and the Dutch West Indies, it was noticed some years ago that budded plants of cacao varied in habit with the part of the scion-mother from which the bud had been drawn. Where the bud was taken from a lateral horizontal branch the resulting plant was of the normal type, that is it was an umbrella-shaped plant tending, as all cacao does, to remain of moderate height with long lateral branches. Where the bud was drawn from one of the erect lush young basal suckers (water-shoots or chupons) a tall erect type resulted.

Knowledge concerning the transmission of a branch-character or habit by a bud has been extended considerably. In the case of Hevea rubber it has become a matter of common knowledge that a constant mode of branching is regularly transmitted thus, and recently a similar fact has been shewn to be true for kapok and coffee. In the course of experiments in budding one type of kapok on another and reciprocal budding of various types of coffee on one another, prostrate types were found to result when buds from horizontal branches were used and normal types where buds were chosen from vertically growing stems. The fact may be of definite commercial value later, and now it has a definite scientific value in that it warns us of possible pit-falls in similar work on other crops. A prostrate type of economic tree may be useful or it may be entirely without value.

Dr. Cramer is working with three types of kapok, the large coarse West Indian type, occurring in the Gold Coast, which in its younger parts is covered with stout conical prickles, the second is the more delicate Java type which rarely is more than a small tree, possesses a longer and more silky fibre which fetches a higher price in the markets than the West Indian type ; and thirdly, a variety of the Java type found in the Eastern parts of Java. Reciprocal

buddings of each type on the others gave some unexpected results. For example, the West Indian type budded on the Java one produced no prickles, a phenomenon which Dr. Cramer explained by stating that by being mounted on already growing, relatively power ful stock, the scion misses the stage of juvenility : its parts pass directly to the more mature prickle-less stage. As is the case with most scientific definitions, it is difficult to say whether this is an explanation or a description, but it is none the less illuminating.

Some light is thrown on the relation between stock and scion by an experiment conducted on rubber by Dr. Cramer. One of the many wild types of Hevea found by him in Brazil in 1912 was a tree with bright sulphur-coloured latex in which little or no rubber occurred. By using this as a stock and a select type of normal Hevea with white rubber-yielding latex as scion, it became possible to investigate the nature of the fusion in so far as latex-canals are concerned. Tapping of these trees shewed that although fusion of the bark and wood of the two types was apparently complete, yet the two types of latex-canals remain permanently separate and distinct. There was no anastomosis of white with yellow, there was no growth of yellow-latex canals across the line of fusion into the scion nor of white-latex canals into the territory of the yellow, and there was no transfusion of yellow latex into the white vessels or *vice versa.*

This permanent isolation of latex-canals by a cut or a join has received striking confirmation at Boenoet Estate. The disease known as ' Brown Bast ' which attacks the tapped area of Hevea-bark, and which caused a bad scare in the rubber-world some years ago and is still the cause of severe loss, is reported by Boenoet to be easily isolated by cutting round the diseased area with a knife. No tissue is removed, merely a cut is made through the bark almost down to the cambium, and the disease has never been known to cross the cut. The method is in operation as the ordinary estate routine means of checking Brown Bast, and it is found that it is not even necessary to throw the treated trees out of tapping. Microscopic examination shews that the severed canals never re-unite or cross the cut, but apparently the severed ends become permanently sealed, as they no doubt do in the case of a join between scion and stock in budded rubber. The provisional explanation of the stoppage of the spread of Brown Bast by the cut is that the unknown carrier of the disease is normally transferred from one part of the bark to another by way of the latex-canals : when these canals seal their severed ends, further transfer must perforce cease.

A final point of interest in the matter of budding may be mentioned. In a field at Buitenzorg, Java, an experiment on crown-grafting may be seen. This began as a trial to ascertain whether it is possible to convert an established field of ordinary or inferior

Hevea by cutting back the trees close to the ground and grafting a stem of select high-yielding type of Hevea on to them. In view of the fact that some of the best yielding types of Hevea normally have a very defective system of branching, in some cases so defective that much loss is caused by splitting of the trunk, atrophy of branches, etc., the question at once arose as to the possibility of building up composite trees in three parts, stock of one type, scion of another and head or branching-system of a third. The idea is likely to spread, and it is well within the bounds of possibility that the adoption of the method may lead to even higher yields of rubber than have been obtained hitherto.

G. G. AUCHINLECK,

Deputy Director of Agriculture.

BULLETIN No. 10.

Department of Agriculture,
Gold Coast.

FUNGI AFFECTING GRAMINACEOUS PLANTS OF THE GOLD COAST.

BY

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FOREWORD.

This *Bulletin* is at once a review of the fungi known up to date to occur on the cultivated and uncultivated grasses of this country and a guide to probably effective methods of controlling the diseases caused by these fungi. It is therefore of unusual value to officers of this and of other Departments of Agriculture and to mycological workers in other countries.

It is probable that certain of the fungi described herein are new to science, while, in other cases, occurrences on certain crops are recorded here for the first time. For these reasons, as well as for the intrinsic merit of the drawings themselves, Mr. Bunting's illustrations are of unusual value.

Two methods of treatment are suggested which should be noted by agricultural officers—namely, the effect of rotation or alternation of crops on the recurrence of certain diseases, and the probable value of seed-sterilization as a means of reducing the incidence of certain diseases. These methods should form the basis of careful field-trials by the Department of Agriculture in order that a definite, numerical statement of their value may be obtained.

G. G. AUCHINLECK,
Acting Director of Agriculture.

ACCRA, 10*th May*, 1927.

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Leaf-blotch ,, ,,

FUNGI AFFECTING GRAMINACEOUS PLANTS OF THE GOLD COAST.

A.—INTRODUCTION.

This *Bulletin* is intended to be a preliminary survey of the fungi causing disease to graminaceous crops in the Gold Coast and its Dependencies. It contains in addition notes on the occurrence of certain saprophytic fungi, and of some of the fungi on related hosts.

The desirability of ascertaining something about local cereal diseases seemed to be worth while in view of the economic aspect of supporting the production of food-crops, and may also be defended on the score of the possible occurrence of human and veterinary diseases as resulting from the presence in cereal food-stuff of such parasites as *Ustilago zeæ, Diplodia macrospora, Gibberella moniliforme, Sphacelia,* etc.

In such a survey as has been possible it has been necessary to investigate the subject in a manner too general to permit of conclusive results in many details. As the work progressed many fascinating problems presented themselves for study and had to be abandoned. So that a considerable amount of work remains to be undertaken particularly with regard to the conditions which predispose the host-plant to disease, and to the degree of pathogenicity of some of the organisms under those conditions.

With cultivation of a primitive standard, where many varieties of the same host-plant are grown with apparent indiscrimination, and under varied conditions of soil and moisture, it is apparent that systematic observations over a long period are desirable to permit the collection of reliable etiological data.

The author is, however, of the opinion that, given more enlightened and efficient cultivation, there would be but little permanent danger to fear from fungous diseases attacking the local cereal crops. It appears obvious from field investigations, that the chief factors which assist the maintenance of diseases to such crops as maize and rice are the custom of sowing a second crop on the same land during the second half of the wet season, and the choice—sometimes compulsory—of soil and moisture conditions that are more or less unsuitable for the crop. It is equally apparent that these conditions should be amenable to correction, or amelioration, by more efficient cultural methods than are generally practised.

The impression gained on visiting a diseased maize farm is usually one of general unhealthiness rather than of specific disease, and that feeling is upheld by the number of diverse fungi which can be found on the host. Such farms are not uncommon toward the end of the wet season, and investigation usually shows that a previous crop has been taken from the same land earlier in the year and that no tillage or other method of soil amelioration has been attempted. The result being that any disease, however scanty, which may have occurred during the first crop is on the spot to deal with the weakened resistance of the later one. By contrast, there is probably no healthier crop in the country than maize sown and cultivated under suitable conditions on recently cleared bush land.

The defects of soil, especially those relating to its physical conditions, and the excess or insufficiency of moisture have a direct bearing on the prevalence of certain diseases, and are usually disregarded by the native farmer. One assumes that he has established an economic equilibrium between his needs and his energy, but there remain the facts, that his methods of cultivation could be improved, and that the import of cereal products is maintained from other tropical, as well as from temperate, countries.

Apart from the effect of primitive cultivation on disease, modern progress as demonstrated by transport facilities by rail and road may be held to be largely responsible for the rapid spread of such an epidemic as occurred in 1924-25 by the outbreak of corn-smut. Whilst there is no question but that the epidemic was only made possible by favourable natural conditions it is doubtful if it could have become so quickly and thoroughly widespread in less recent years when travelling was slow and the staple food-crop less liable to transportation.

The author regrets that an anticipated visit to the Northern Territories in connection with this work was not realised. As will be seen from the records of material collected most of the diseases are fairly well distributed over the areas which have been visited in the Colony and Ashanti—a fact which appears to indicate that they have been established for some time.

Their effect on the crops necessarily varies considerably under the varying conditions which obtain locally, but, where so little is known of the results of native cultivation it is almost impossible even to estimate the loss due to fungous diseases for any one year.

In addition to the desirability of affording the crops a suitable cultivation, including an efficient rotation, as a means to improve the host-plants' resistance to the attack of disease, it is thought that the disinfection of seed would considerably assist to diminish the incidence of some diseases in many localities. Trials are being undertaken with the view to ascertain the most practical and efficient method whereby the farmer might be encouraged either to free his seed from potential pathogens or to obtain disease-free seed from official sources.

It is probable that some of the fungi, to which no specific determination has been given in this publication, may be new to science. Where possible, illustrations and a description have been appended in the hope that the organism may be recognised and information received of its proper designation. No apparently new species has been named herein as such because of the desire to avoid à possible multiplicity of synonyms—a not unlikely contingency to be caused by an ardent systematist with the facilities offered by work in such a country as West Africa.

For very valuable assistance in determining the position of the named species, and in clearing up their synonymy, the author is under a real debt of gratitude to Mr. E. W. Mason, of the Imperial Bureau of Mycology, Kew, and to the Cambridge University Press for the excellency of the reproduced, coloured illustration.

B.—DISEASES OF MAIZE.

(Zea Mays L.)

CORN SMUT.

(Ustilago Zeæ (Beck.) Ung.)

The history of this disease in the Gold Coast Colony and Ashanti is not known with any degree of accuracy. It is said to have occurred in the Central Province some years ago, and to have been found on the road from Sekondi to Impohor in 1917, but unfortunately these statements cannot be authenticated.

In any case such attacks cannot have been severe, since the occurrence of so obvious a disease on the staple food of the country, it at all common, could not have been overlooked, nor is it likely that a severe attack would have been forgotten by cultivators who have recently been questioned as to their knowledge of the disease and who have been unanimous in declaring it to be previously unknown.

Enquiries of neighbouring countries have elicited the information that, with the exception of a district in Senegal, corn-smut is not known to exist within a very large radius of the Gold Coast.

In July 1924 an outbreak of the disease was reported from the Central Province, and a rapid survey of the corn-areas was made during the main crop of that year, which showed a distribution strongly suggesting that the railway and two well used roads had carried smut from one of the chief ports of entry. During the second crop of that year many new localities were recorded as infected, and the main crop of 1925 showed an extension eastward into British Togoland.

An attempt to estimate the comparative incidence of disease per acre during the second crop of 1924 was rendered almost impossible by the irregular manner of sowing, and by the fact that all the culms arising from the number of seeds planted in one hole are allowed to develop by native cultivators. In one of the worst cases seen by the writer it was estimated that at least 25% of the culms were infected and that 66% of the stands contained infected culms.

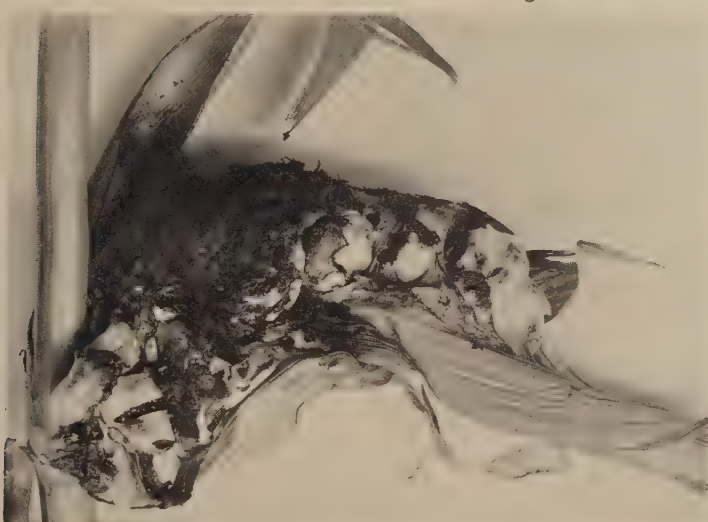
Whether or not corn-smut be endemic, the rapid dissemination of the disease which assumed epidemic proportions in 1924-5, and subsequently diminished, indicates that favourable conditions for the development of the parasite then obtained. An attempt to correlate available meteorological records with the outbreak has,

PLATE II.

DISEASES OF MAIZE.

A

C



B

H.A.D. *photo*

Corn Smut (*Ustilago Zeae* (Beck) Ung.)

A and B. On ears.

C. On tassels, showing production of female organs (corns) in the male inflorescence.

however, afforded no light on that point. The rapidity with which the disease spread over a wide area may be regarded as being assisted by the modern facilities for quick transit which are provided by railway and motor roads, as well as by the cultural conditions under which maize is normally grown in this country.

Symptoms.

The well-known hypertrophic symtoms, shown in Plate II., differ in no way from those familiar in nearly all other maize countries. The majority of cases consist of infection in the axils of the leaves, or of female flowers, resulting in the transformation of potential grain into soft tumours of varying size which are glistening white until they rupture and disclose black powdery masses of spores and distorted fibres.

Similar tumours arise on the culms or leaves, and frequently the staminate inflorescence of a smutted plant produces female organs which give rise to more or less normal grains or tumours. The effect on the host-plant therefore consists of a considerable diminution of grain that can be utilised either as food or seed. Weatherwax [25 :p.79]* states regarding corn-smut that " this fungus destroys the ear in many instances, and is very objectionable when introduced into foods made from the plant for man or for live stock. In silage its effects are obvious. Cattle that have eaten large quantities of ears partly destroyed by smut sometimes suffer from poisoning similar to that due to the ergot of rye ".

Infection.

The chlamydospores released from a mature tumour are capable of resting for a considerable period before germinating in moisture, but, given a suitable medium, they may germinate at once. From the promycelium so developed arise small sporidia which by budding increase their number, more or less indefinitely, dependent upon the nutritive value of the medium in which they arise. Infection takes place by the germination of a sporidium in contact with any part of a maize plant which is actively growing, the older parts of the host-plant being resistant to attack. Infection is practically always localised, and results in the formation of a tumour within about three weeks.

Predisposing Conditions.

In other countries it has been found that infection is favoured by the tender development of the host-plant caused by forcing conditions which accelerate its growth and afford a surplus store of food, and by a moist atmosphere. In this country where the native farmer usually sows two successive crops on the same land, the parasite has an obvious opportunity to increase its incidence of attack.

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*Throughout this Bulletin numbers in square brackets refer to the Literature cited in the List on page 50.

Close planting of corn may also be considered as of assistance to the disease since suitable moisture conditions are thereby assured.

Control.

The points to be remembered in attempting to combat corn-smut are :—

(1) the potentiality of chlamydospores to germinate after a period unfavourable to germination, which period may amount to some years;
(2) the ability of chlamydospores to retain viability after passing through the alimentary canal of animals;
(3) the necessity of moisture and a nutrient medium, *e.g.*, manure, rich soil, for the germination of chlamydospores;
(4) the saprophytic ability of the fungus to remain viable in its sporidial stage given a suitable medium;
(5) infection by sporidia;
(6) infection restricted to the actively growing parts of the host; and
(7) distribution of both kinds of spores by wind, insects and other animals.

Experiments to prevent the development of corn-smut are said to have been started in 1760, and are now being directed to the breeding of resistant strains of maize.

Methods of cultivation *e.g.*, selection of seed from non-infected sources, satisfactory rotation and spacing, are usually all that is required in other countries to reduce the disease to such a percentage of infection that it would be uneconomical to apply special methods of control such as spraying.

In this country, the habit of sowing a second crop on infected land should be discontinued; the use of grain obtained from an infected crop should be avoided for seed purposes; a rotation which prevents maize from being sown within three years on the same land should be adopted; all infected material should be burnt before its tumours are fully developed; all maize trash on an infected farm should be burnt, and no domestic animals permitted to eat uncooked smutted corn.

Causative Fungus—*Ustilago zeæ (Beck.) Ung.*

SORI, produced within the hypertrophied epidermis of the host, forming swellings up to 60 microns long and 25 microns wide.

SPORES, globose or shortly elliptical, light brown, finely spinulose; 8 to 11 microns;

PROMYCELIUM, cylindrical, 3 to 4 times septate, bearing numerous spindle-shaped sporidia.

ON all parts of Zea Mays L., generally distributed throughout the maize producing area. 1924 and 1925.

BLACK BUNDLE DISEASE OF MAIZE.
(Cephalosporium acremonium Corda.)

This disease, which was described in 1924 by Reddy and Holbert [15] for America, appears to occur in various parts of the maize producing districts of this Colony, an authentic case having been collected at Asuansi in June 1926, and many undetermined cases seen elsewhere which, in the light of more recent knowledge, would no doubt be correctly diagnosed under this head.

In very many farms there may be found plants bearing one or more of the group of symptoms associated by the above workers with the black-bundle disease, and the desirability of further work on such local manifestations seems obvious.

Symptoms.

Reddy and Holbert give as the most distinguishing symptom the presence of blackened vascular bundles in the stalks and sometimes in the leaves. This symptom occurs fairly frequently in some districts here, as do the following associated symptoms which are frequently additional demonstrations of the disease—a red or purple discolouration of the leaves or stalk extending downwards from the apex of the plant, the formation of imperfectly developed ears, barren stalks, or stalks bearing a number of ears at one node, and excessive suckering.

The above-mentioned workers consider that whilst some of the above symptoms may be caused by other agents, the presence in the host-plant of *Cephalosporium acremonium* Corda, is one of the most important causes in producing the group of symptoms associated with black-bundle disease of maize, and state that "The group of symptoms under discussion may occur to some extent without the presence of *C.acremonium*. Only careful examinations and analyses can determine when this organism is responsible for these symptoms. It is also true that infections may be quite general in corn without the presence of any of these symptoms to a marked extent, except the blackened fibro-vascular bundles" [15 : p. 189].

Cephalosporium acremonium has frequently been found in this country associated with diseased maize material and other plants, and it was undoubtedly present in the blackened bundles of a culm collected at Asuansi.

Control.

Reddy and Holbert advise the avoidance of grain from plants showing any of the group of symptoms of the black bundle disease for use as seed. They consider the best method of control will come with the development of resistant strains of maize, and state that preliminary seed treatment experiments offer promise of control of this disease.

Causative Fungus—*Cephalosporium acremonium* **Corda.**

The fungus is characterised by its spherical, mucilaginous heads of nonseptate spores borne on simple conidiophores on a hyaline, infrequently septate, mycelium.

In America the organism is said to enter the seed through the vascular system, thus permitting the disease to be seed-borne. Its presence does not generally affect the early vigour of the resulting plants, so that tests of germination do not indicate infection, and the symptoms of disease are not usually evident until the host-plant is well established.

MYCELIUM,	creeping, hyaline, infrequently septate, bearing short, awl-shaped, usually non-septate conidiophores, up to 20 microns in length ;
SPORES,	cylindrical, hyaline, 4 to 6 by 1.5 microns, collected in spherical heads at apex of conidiophores by mucilage.
FROM	discoloured vascular bundles of Zea Mays L, Asuansi.

BROWN SPOT OF MAIZE.
(Physoderma Zeæ-maydis Shaw.)

This disease of maize has been collected in Ashanti and in the Eastern Province of the Colony, and has been found of such prevalence as to affect up to 46% of the plants, and 54% of the stands in a field of young corn.

It was first recorded in India, later in the United States of America. A similar, and probably identical, disease was previuosly described in Japan, but the causative organisms of the two diseases have not been compared.

Symptoms.

The presence of the fungus which causes "brown-spot" is readily discernible on an infected plant by the dark, purplish-brown spots which may occur on the blade or sheath of the leaf (Plate III., figs. C, B, D), or on the culm (fig. D), rarely on the husks of the ear.

The spots occur in irregular masses, or distinct from one another and from the normal green colouration for the healthy tissue as is shown in figure C. They measure at first not more than one millimetre in diameter, but frequently develop in size up to five millimetres. These usually orbicular, discoloured areas may remain distinct, or, by their confluence and by the necrosis of intermediate tissue, give the appearance of a more or less solid, purple-brown discolouration to a large area of the host similar to the effect produced on the leaf-sheaths of figure A.

Frequently the appearance of the spots is heralded by a yellowish change in colouration of the area affected. The ultimate result produced by the fungus is the desiccation and rupture of the epidermis and the production of dusty masses of brown sorangia.

PLATE III.

DISEASES OF MAIZE.

Figs. A to D.—Brown Spot (*Physoderma zeae-maydis* Shaw). Fig. A.—Severe infection of leaf-sheaths of young plant. B.—Periodic infection caused by moisture lodging at different levels as leaf-sheath and culm developed. C.—Infection of lamina and auricle. D.—Old infection about to liberate sporangia.

Fig. E.—Leaf-spot II (*Acrothecium lunatum*, see p. 16).

Fig, F.—*Marasmius* leaf-blotch.

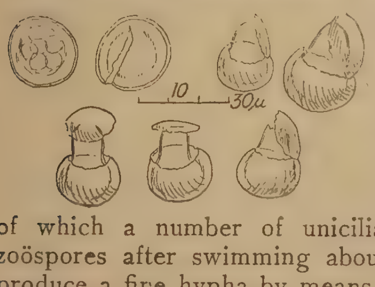
Effect.

The actual damage caused to a maize plant by the parasite may be almost negligible if infection does not take place until the grain is set and ripening, but when a heavy infection occurs at an early stage of the host's development—as is shown in fig. A Plate III—the production of grain suffers by restriction, either partial or complete, of the normal function of the leaves, and the whole plant may be destroyed by an attack on the nodes ultimately causing the culm to break.

The fungus is considered as responsible for one of the worst diseases of maize in the United States of America, where plant quarantine measures against it were established in 1916. Very serious damage to the crop is said to be caused by it in those States which have a considerable amount of moisture and a continuous high temperature during the early part of the corn-season. Observations of the disease in this country also indicate similar predisposing conditions.

Infection.

Physoderma Zeæ-maydis belongs to a primitive group of fungi which inhabit the cells of their host-plants. The brown-spot disease of maize is reproduced by the development of numerous sporangia within the cells of the host tissue. Upon the disintegration of the latter the sporangia escape, and are distributed by various agents. They are sufficiently thick-walled to be resistant to many months of drought, but in contact with water germination is rapidly effected in the manner shown in the accompanying figure. After segmentation of the contents of a mature sporangium, a fissure appears in the outer wall and the resulting segment is either completely detached or is pushed aside by the swelling endosporangium which is protruded to form an inverted funnel-shaped vesicle, from the apex of which a number of uniciliate zoöspores are released. The zoöspores after swimming about for some time settle down and produce a fine hypha by means of which the epidermis of the host-plant is penetrated and its cells permeated; sporangia are developed within the cells, and the life cycle begins again.



The necessity of free moisture for the act of infection is obvious, and is demonstrated by the localised occurrence of the fungus on an infected plant. Wherever water is retained by parts of the plant, *e.g.*, leaf-sheath, base of lamina, auricles, there infection is most frequent. By the development in length of the internodes and the growth of the leaves new areas are continually

being exposed to favourable conditions for infection. An illustration of the periodicity of the infection of a leaf-sheath is shown in figure D, Plate III where successive infections have occurred as moisture accumulated every night between the auricles of the lower leaf and the leaf sheath they clasped.

It has been found in America that the resting sporangia "live over winter on the diseased plants and in the soil and are carried in spring and summer by wind and other agencies to the young corn plants" [24].

The incidence of attack is, as might be expected, markedly influenced by the period of time which is allowed to elapse between successive crops of maize. The author is indebted to Mr. T. Hunter of Kumasi for data of the 1926 maize crop which show that, on land continuously under maize since 1923, 60.2% of the culms were affected, and 12.7% destroyed, by the disease, and 55.9% were affected and 29.8% destroyed on a plot which bore maize the previous year, whereas on virgin soil only 2.1% were affected and 0.75% destroyed, and on plots not under maize for the previous two or three years there were rather more than 15% of the culms affected and from 2 to 5.8% destroyed.

Control.

From a consideration of the life-history of the parasite it is apparent that an attempt to control the brown-spot disease of maize should include the destruction of diseased material before the sporangia have been liberated; the institution of a satisfactory rotation of crop, and of necessity the reduction of excessive moisture conditions.

The treatment, with alcohol and subsequently with sulphuric acid, of grain used as seed has been proved to be effective against *Physoderma* [26], and other methods of seed disinfection should be equally successful.

Causative fungus.

Physoderma Zeæ-maydis Shaw.

SPORANGIA	ellipsoid ovate to globose, 20 to 25 by 14 to 25 microns, light-brown uniciliate.
ZOOSPORES	
ON	culms and foliage of *Zea mays* L., Juaso, Kumasi, Ejura, Mampong Ashanti, Odumase, Axim and elsewhere.

LEAF BLIGHT OF MAIZE.
(Helminthosporium turcicum Pass.)

Various popular names are given to this disease in other maize producing parts of the world, *e.g.*, leaf-spot, leaf-scorch, white blast, yellow-leaf, helminthosporiose. It occurs in many parts of the Colony and Ashanti, and will no doubt be found in all the corn areas of the forest belt. The list of countries from which leaf-blight of maize has been reported is a long one; Butler [2 : p. 201] gives

beside India, Italy, the United States of America, South Africa, Japan and the Philippines, Drechsler [4 : pp. 712-3] adds France, New South Wales and possibly Russia, and Small [19 : p. 11] records its occurrence in Uganda.

Symptoms.

Affected portions of the leaf are at first small and chlorotic, increasing in area into longitudinal blotches of a straw to grey-brown colour, and usually become demarcated by a narrow band of a slightly deeper tone (Plate I., fig. B). These lesions which consist of the desiccated tissue of the host may occupy a considerable area, and are practically always of greater length than breadth. Under moist conditions their surface becomes covered with olive-green, velvety masses of conidiophores, and the whole leaf eventually withers in a manner suggestive of the effect of fire or frost.

Effect.

The amount of damage done to the host appears to depend upon the value of the affected leaves to the plant. Thus the destruction of old leaves which may already be more or less moribund at the time of attack has little effect upon the plant's development. But when external conditions favour an attack upon young foliage considerable damage may be caused by retarding development, and according to some observers to such an extent that the host is killed. Reinking [16 : p. 140] reports on the destructiveness of this disease in the Philippines as having destroyed fields of corn. it being "especially severe on newly introduced corn which is not acclimated, and is in a weakened condition".

Control.

The means by which the parasite retains its vitality during the period when no economic host crop is available is not known; it is said to occur on sorghum in America [22] and in India [11] [18], and in the latter country its development has been induced on wheat, barley, oats, sugar-cane and rice [18]. In this country it has so far only been found on maize and *Andropogon halepense*. So that it is possible that it persists by utilising other hosts than maize.

In this connection it should be remembered that both Shaw [18] and Mitra [11] have stated that the parasite, whilst morphologically similar on maize and sorghum in India, appears to be divided into biological strains, each of which can infect the host-plants mentioned above.

In the absence of further knowledge regarding the life-history of the fungus, preventive measures against its occurrence can only consist of rotation of crops and destruction of infective material.

Infection.

According to Mitra [11] infections take place either directly through the epidermis of a maize leaf or through stomata. The conidia of the fungus in this country germinate readily in water at both poles, it has never been observed to take place from intermediate cells, but occasionally two germ tubes have been produced from one of the polar cells. The spores of *H. turcicum* are said to retain their vitality for a period of three months in the Philippines, and Marquez [8] reports positive results from the infection, with pure cultures of the fungus, of soil in which maize seed was germinated.

Causative fungus.

Helminthosporium turcicum Pass. (syn. *H. inconspicuum* C. & E.) Plate IV, figs. A—D.

Only the conidial stage of the parasite is known. It differs from other species of the same genus found on graminaceous hosts here, by its stouter, nearly straight sporophores, and by the protruded, narrow hilum and decidedly tapering outlines of its usually straight spores. Of the figures shown on Plate IV, the spores cultivated on tap water agar, denoted by B, may be taken as typical; that marked C shows somewhat exceptional breadth, whilst the sporophore of figure D from the leaf of *Andropogon halepense* is rather longer than usual.

SPOROPHORES,	brown, almost straight, 100 to 380 by 7 to 10 microns with 3 to 8 septa, arising in groups of 1 to 3 from stomata.
SPORES,	fuliginous; straight or very slightly curved, tapering to both ends, widest usually below the middle, 3 to 7 times septate, with a narrow, pronouncedly protruding hilum, 45 to 128 by 15 to 28 microns.
ON	leaves of *Zea mays* L. at Aburi, Krobo, Ejura, Juaso and Kumasi, and onl eaves of *Andropogon halepense* in the Krobo country.

LEAF-SPOT OF MAIZE—I.

(Ophiobolus heterostrophus Drechsler; conidial stage.)

Considerable confusion has arisen from local collections of diseased maize foliage bearing species of *Helminthosporium*. A collection made at Aburi agreed in symptoms, and in the conidial stages of the causal organism, with those described by Drechsler's paper on "Leaf Spot of Maize caused by *Ophiobolus heterostrophus*, n.sp., the ascigerous stage of a *Helminthosporium* exhibiting bipolar germination" [5]. Later a similar conidial form was found to produce the same symptoms on maize grown at other localities.

Distribution.

Drechsler—whose paper has disentangled the muddle which had confused the causal organisms of leaf-blight and leaf-spot—states therein that his leaf-spot occurs on maize and teosinte (*Euchlæna mexicana* Schrad.) in the Philippines, and on maize in Florida, and that it "is probably widely distributed in tropical and sub-tropical maize-growing regions, having evidently been confused with leaf-blight which occurs in the same territory".

Symptoms.

The lesions are buff in colour, bordered by a brown margin, irregularly elongated up to 3 mm. in length, and rarely exceed in width the space between two adjacent veins. Figure A of Plate I is characteristic of their appearance. Large numbers of spots occur and apparently cause considerable damage to the leaf.

Causative fungus.

The ascigerous stage of *Ophiobolus heterostrophus* has not yet been observed in this country, although small, stromatic-like bodies have been found in the mycelium of dried-up cultures which suggested incipient perithecia.

Plate V shows the difference of the sporophores and spores as compared with those of *Helminthosporium turcicum*; the former being narrower, whilst the conidia are more curved, less wide in proportion to their length, contain more septa, and do not show the protruded hilum characteristic of the latter species.

The determination of the local fungus has been based on a comparison of the long-spored species of *Helminthosporium* found in Baker's Fungi Malayana, No. 239 in Herb. Kew, Dr. Drechsler having stated (in lit.) that the long-spored form often present in this exsiccatum is his species.

SPOROPHORES, 140 to 255 by 8 to 10 microns, brown, 3 to 5 times septate arising in groups of 1 to 3 from stomata;

CONIDIA, 60 to 125 by 12 to 17 microns, curved, tapering to both ends, 5 to 11 times septate, with an inconspicuous hilum.

ON foliage of *Zea mays* L. at Aburi and Satatsu, Ashanti; probably on male inflorescences of *Zea mays*, Aburi and elsewhere.

Dreschsler's diagnosis of the ascigerous stage [5 : p. 724] may be summarised as follows :—

PERITHECIA, erumpent, black, somewhat ellipsoidal or sub-globose, 0.4 to 0.6 mm. in diam., 0.4 mm. high, with ostiolate beak;

ASCI, numerous, short stipitate, subcylindrical, 160 to 180 by 24 to 28 microns, containing four spores arranged in a multiple, heterostrophic, helicoid manner;

ASCOSPORES, filamentous, fuliginous, five to nine times septate, constricted at septa, 130 to 340 by 6 to 9 microns.

LEAF-SPOT OF MAIZE.—II.

Another leaf-spot of maize with symptoms which appear to be distinct from those of the previously mentioned disease has been collected on separate occasions at Juaso in Ashanti and from other localities. In the first collection made at Juaso there were present on the lesions two species of Dematiaceous fungi the more evident of which is discussed here under the name *Acrothecium lunatum*, whilst its companion appears closely to approach *Helminthosporium sativum* (pl. IV, fig. J.) The disease was common on a field of maize which had to be condemned on account of the number and prevalence of the diseases present.

More recently there have been found in the same district mature maize plants the foliage of which was abundantly affected by spots from which nothing but *Acrothecium* could be obtained. Still later a *Fusarium* occurred with *Acrothecium* in cultures inoculated direct from a spot. So that, whilst the constant association of *Acrothecium lunatum* with these spots and the taxonomic interest of the fungus appeared to justify its inclusion here, it is not to be assumed that this species is necessarily the causative organism.

Symptoms.

The spots (see Plate III, figure E), measuring from 0.5 to 7.0 mm. are occasionally in contact with one another but appear not to coalesce, in colour they are greyish buff, tending to zonate around a small, white, translucent spot, and bordered by a dark purplish-brown margin which is again surrounded by an irregular areola of chrome yellow. The fructifications of the associated fungus occur in large numbers on both surfaces of the leaf.

Associated Fungus.

Acrothecium lunatum Wakker sec. Mitra.

In 1916 Saccardo [17] published a new species of *Helminthosporium* on maize under the name of *H. curvulum*, which he later recorded as occurring on the leaves of *Bambusa blumeana*, and in 1919 authentic material of the fungus on the male inflorescences of maize (Baker's Fungi Malayana, No. 239) was published. In this exisccatum there are two distinct species both with curved spores, those of the one species being much shorter and with constantly less septa than the other. As Drechsler [5] points out, Saccardo's name *H. curvulum* refers to the smaller spored of the two species. The Gold Coast material has been compared with Baker's numbers 217 and 239, both of which are labelled *Helminthosporium curvulum* Sacc. in *Herb. Kew*, and may be regarded as authentic material since Saccardo determined the exsiccata published by Baker.

Spores and sporophores of Baker's No. 217 are shown as figure H on Plate VI, those of Baker's No. 239 are figured on p. 710 of Drechsler's paper on *Ophiobolus heterostrophus* [5].

A comparison of these figures with those of the Gold Coast material (Plate VI, fig. A-G) confirms the identity of the latter with Saccardo's *Helminthosporium curvulum*.

A culture of the local fungus from maize has been kindly determined by Mr. Mitra as *Acrothecium lunatum* Wakker as known to him in India where it is a saprophyte or weak parasite on many grasses. Mitra [10] also records the species as occurring on maize tassels, so that, *Acrothecium lunatum* Wakker and *Helminthosporium curvulum* Sacc. may be considered to be synonymous. To what genus the fungus should ultimately be referred would appear to depend upon further observations. The development of the conidial cells offers differences from that of the cells of *Helminthosporium*; in culture the number of spores borne pleurogenously would seem to indicate a closer affinity to *Spondylocladium* than to *Acrothecium*; whilst Maublanc and Delacroix [3 : Pl. XVIII, fig. 7] illustrate similar conidia as preceding the appearance of the perithecia of *Leptosphæria sacchari* van Breda de Haan on sugar-cane. The fungus is here recorded under Wakker's name as being the older designation, and until the matter has been more fully investigated.

Occurrence.

In addition to its presence on leaf-spot of maize (Pl. III, fig. E, and Pl. VI, figs A,D,E), strains morphologically similar to *Acrothecium lunatum* have been collected in this country,

- (*a*) from leaf-spots attributed to the conidial stage of *Ophiobolus heterostrophus*,
- (*b*) in association with a species of *Helminthosporium* on necrotic maize auricles (Pl. I, fig. E),
- (*c*) as a mildew associated with the same species of *Helminthosporium* on maize leaf-sheaths (Pl. VI, fig. G),
- (*d*) in association with *Helminthosporium oryzæ* on the glumes of rice (Plate VI, fig. F),
- (*e*) on the foliage of sugar-cane, and
- (*f*) on the foliage and glumes of Guinea-corn.

Shaw [18] records it on *Setaria italica*, *Panicum frumentaceum*, *Eleusine coracana*, and many other plants in India, and as already stated the same fungus has been described on *Bambusa blumeana*, and on sugar-cane elsewhere.

Pathogenicity.

The degree of pathogenicity of the Gold Coast fungus has yet to be determined by experimental work. Such inoculations of young maize leaves as have been made have given inconclusive results. It is usually found in association with other fungi, some of which are not definitely known to be parasitic. Shaw [18] considers it to be a weak parasite producing small spots in India, and that is possibly its habit here.

There is, however, always the possibility that the *Helminthosporium*, with which it is so frequently associated on the leaf-spot mentioned above, may prove to be the conidial stage of *Ophiobolus heterostrophus* in which case it might be fair to assume that the apparent difference between that leaf-spot and the one described by Drechsler is a modification of the latter caused by the presence of *Acrothecium lunatum.*

The fungus grows readily on artificial media. On cassava mush agar the mycelial hyphæ tend to form strands before producing somewhat elongated sporophores, and in old cultures, to produce submerged subicula of darker, thick walled, frequently septate and swollen hyphæ that suggest catenulate chlamydospores. Conidia developed in either cassava mush agar or tap water agar are at first almost spherical, after division in a horizontal plane the apical cell becomes larger and both cells again divide horizontally, so that the mature spores in these media are more generally developed in a straight line, as is shown in figures B and C of Plate VI, than in a bent or curved manner. The spores are borne acrogenously but by development of the apex of the conidiophores large numbers of apparently pleurogenous spores occur in luxuriant growth.

SPOROPHORES,	brown, straight, slightly geniculated toward the apex, 4 to times septate, 65 to 250 by 5 to 7 microns, up to 340 microns in length on rice glumes, arising in groups of 2 to 5 from stomata.
SPORES,	light brown, sometimes almost hyaline with darker central cells 3 to 4 times septate, third cell from base always the largest, apical cell rounded and frequently borne in a contorted manner to produce a curved or rectangular axis, basal cell narrowed to a conspicuous hilum, 20 to 32 by 9 to 12 microns ;
ON	foliage of *Zea mays* L., Juaso, Aburi, Bunso, Odumase, Asuansi ; on glumes of *Oryza sativa* L., Adebrem ; on foliage of *Saccharum officinale* L., Asuansi ; on glumes of *Andropogon sorghum* L., Asuansi.

MAIZE RUST.

(Puccinia maydis Bereng.)

Maize rust is fairly commonly distributed in this country, and occurs in many other of the warmer parts of the world including Southern Europe, India, Australia and the United States of America.

The disease is rarely of considerable economic importance, but occasionally, during periods of excessive humidity, it may develop sufficiently early, and to such an extent, as to cause the affected foliage to wilt and dry up with consequent loss of crop.

Symptoms.

Small yellow spots occur on both sides of the leaf, become reddish-brown and elongated, and rupture, disclosing, between the longitudinal lips of the burst epidermis, pustules of light brown uredospores. Later the spots become larger and black, and reveal similar pustules of dark teleutospores.

Control.

Operations for the control of maize rust are usually not considered as an economic proposition; the most practicable method in this country would be to remove rusted leaves or, in the case of bad infection, the whole plant, and destroy them by fire.

Causative Fungus.

Puccinia maydis Béreng. (Plate IX, fig. D).

The fungus is said to be heterœcious, the aecidial stage having been demonstrated elsewhere to occur on species of *Oxalis*, and to have been known previously under the name of *Aecidium oxalis* Thuem. The aecidial stage is not yet known to occur in this country.

It is also recorded on *Euchlæna mexicana*—a near relative of *Zea mays*—for America, but does not occur on *Sorghum* in spite of its synonymous binomial *P.sorghi* Schw. (non Fckl.)

AECIDIAL STAGE	not known locally.
UREDINIAL STAGE,	sori amphigenous, numerous, sometimes confluent pustular; spores usually globose, sometimes ovoid, light yellowish brown, finely spinulose, 25 to 30 by 23 to 28 microns;
TELEUTOSPORES,	arising from periphery of uredo sori, chestnut brown, smooth, ovate or oblong, constricted at septum, bluntly pointed at apex, epispore thick especially at apex, 33 to 45 by 18 to 20 microns; pedicel, persistent, light brown, long, 4 microns in width increasing to 5 at the top;
ON	the foliage of *Zea mays* L., Bisa, Kibi, Bekwai, Kumasi, Ejura, Aburi.

BLACK-AURICLE DISEASE OF MAIZE.

The condition depicted by figure E of Plate I has been found to be frequent in many farms. No detailed observations of it have been made as it is not considered to be of sufficient economic importance, although it may indicate a general unhealthy condition of the host-plant especially when it occurs on the younger leaves.

Symptoms.

The symptoms are obvious; the almost colourless wedge-shaped areas, situated between the blade and sheath of a leaf and expanded to form auricles, become brown at the edge, the discoloration extending inwards to the mid-rib, darkening to black, and usually sharply demarcating that area from the normal coloration of blade and sheath.

The most commonly found fungi on dead or moribund auricles are *Acrothecium lunatum* Wakker (for a description of which see p. 16), and a species of *Helminthosporium* closely allied to if not identical with, *H.sativum* Pammel, King and Bakke.

Associated Fungi.

The latter fungus closely resembles that described on p. 16 as probably the conidial stage of *Ophiobolus heterostrophus* Drechsler, except that on artificial media the sporophores are more contorted by more frequent and pronounced geniculations at the distal end, and that the spores are usually darker in colour.

The spores of this fungus, figured under G of Plate IV, were obtained from a black auricle, and those marked H were developed on tap-water agar from the same source.

The same species frequently causes black, mouldy patches on the leaf-sheaths and husks of old maize plants, on which more or less moribund media it cannot be regarded as more than weakly parasitic. Figure E of the same plate shows spores and sporophores taken from such a situation, and figure F. a tap water derivative of the same.

As has been mentioned (p. 16) a *Helminthosporium* species, considered to be identical with this fungus, occurs in association with *Acrothecium lunatum* on certain leaf spots of maize.

Whether the fungus is distinct from the conidial stage of *Ophiobolus heterostrophus*, or is to be regarded as *Helminthosporium sativum*, requires investigation based on further cultural trials. It may be described as follows:

SPOROPHORES, 100 to 330 by 8 to 9 microns, brown, 6 to 9 times septate, more or less geniculated at distal end; in artificial media, up to 500 microns in length, up to 30 times septate, contorted by frequent geniculations at distal end, sometimes branched with a straight and slender basal portion, arising from torulose mycelium;

SPORES, 30 to 130 by 10 to 17 microns, olivaceous, 4 to 13 times septate, straight or slightly curved, usually tapering to distal end, with enclosed and conspicuous hilum, in artificial media they are usually shorter and more ellipsoidal, 4 to 9 times septate, darker in colour with the basal and apical end sometimes conspicuously lighter. Germination is bipolar.

There has also been found occasionally on black auricles a second species of *Helminthosporium* with dark brown, straight, 7 to 15 times septate, conidiophores, which measure up to 470 microns in length, and bear a few, fuliginous, usually rostrate, 8 to 17 times septate, spores, with a protruded hilum, and a measurement of 80 to 260 by 14 to 22 microns.

LEAF BLOTCHES OF MAIZE.

Considerable difficulty has been experienced in an attempt to ascertain the causes— and to differentiate their effects—of the numerous elongated areas of dead tissue which occur on mature maize leaves locally, and which may conveniently be termed leaf-

blotches. Of these, some appear to be caused by sun-scald and become the medium on which numerous saprophytes develop, whilst other causes no doubt occur. Figure C of Plate I. illustrates a case in which the cause of disease has been concealed by the numerous fungi which have invaded the affected area—ten distinct organisms having been found thereon.

There are, however, three leaf-blotches of maize which appear to be fairly distinct—that figured B on the same plate has been described as leaf-blight caused by *Helminthosporium turcicum* (p. 12), and is differentiated by its grey, velvety covering of conidiophores; the one, now to be described, with which *Diplodia macrospora* Earle is associated, (illustrated by figure F of Plate I) may be recognised by the presence of easily discernible, black pycnidia, and that which follows (p. 22), caused by a species of *Marasmius* and figured F on Plate III, is much lighter in colour, with a more translucent substratum and bears typical, though small, sporophores.

DIPLODIA MACROSPORA EARLE ON MAIZE FOLIAGE.

Symptoms.

The lesions, which may not be more than ten millimetres in width, extend in a direction parallel to the axis of the leaf blade for a distance of as much as thirty centimetres, and in severe cases occur in numbers on any one leaf. In slight affections the lesions may be much smaller. They are usually of a clear, straw to light cinnamon-brown, colour with a somewhat darker border which tends at the extremities of the affected area still further to increase its length by acute prolongations into the normally coloured tissue.

The black pycnidia appear as small dots scattered in lines on both surfaces, but principally on the under side, of the leaf. On the leaf-sheath the effect of the fungus is less noticeable, but its presence is clearly demonstrated by the occurrence of the distinct black dots that denote pycnidia.

The disease may or may not be serious according to the incidence of attack which appears, by observation only, to depend rather on the general condition of the host-plant than on the positive pathogenicity of the organism.

Associated Fungus.

Diplodia macrospora Earle (Plate VIII, fig. A).

Rather large, black pycnidia develop below the epidermis of the host and at maturity produce an erumpent ostiole; they are usually more or less oval on a horizontal plane, measuring up to 550 microns in their longer diameter. The spores are olivaceous-brown, with somewhat thick walls, usually once septate, though three celled

spores have been found in nearly all pycnidia examined, they are more or less cylindrical in shape, many of them being irregularly clavate, and measure up to 90 microns in length by 10 microns in width.

The taxonomy of the fungus is open to discussion. It is recorded here as *Diplodia macrospora* Earle, because that is the binomial by which it is known in the United States of America. It is, however, considered by some systematists as being a form of *Diplodia zeæ* (Schw.) Lev., a species that is responsible for a great deal of damage to maize in America, and one which has not yet been found in this country. *D. zeæ* has been referred to *Macrodiplodia* by Petrak (Ann. Mycol., XXI, p. 189, 1923), and to a new genus *Phæostagonosporopsis* by Woronichin (La Défense des Plantes, Leningrad, II, pp. 331-4, 1925), whilst *D. macrospora* Earle is considered by von Höhnel (Hedwigia, LX, pp. 147-8, 1918) to be the same fungus as was described by Sydow (Ann. Mycol., XV, p. 258, 1917) as *Stenocarpella zeæ nov. gen. nov. spec.*

The synonymy is considered to be :—

Stenocarpella zeæ Sydow, 1917.
Macrodiplodia macrospora von Höhnel 1918.
Diplodia zeæ (Schw.) Lev. var. *macrospora* (Earle) von Höhnel 1918.
Macrodiplodia zeæ (Schw.) Petrak & Syd. var. *macrospora* (Earle) Petrak & Syd. 1923.

Diplodia macrospora also occurs on the cobs of maize, and is further discussed under ear-rots on p. 26.

SPOROPHORES,	scattered, black, large, more or less oval in horizontal plane, subepidermal, erumpent by ostiole, 300 to 550 by 280 to 460 microns horizontally ;
SPORES,	olivaceous-brown, thick walled, straight or slightly curved, cylindrical or irregularly clavate, once or twice septate' usually constricted at septum, rounded at apex, more or less elliptic at base. 45 to 86 by 6 to 9 microns ;
	on foliage of *Zea mays* L. Juaso, Ejura, Essiama.

MARASMIUS SP. ON MAIZE FOLIAGE.

An uncommon affection of maize foliage is figured on Plate III, figure F. The disease has only been recorded on three occasions in this country and has not apparently been found elsewhere.

Symptoms.

Large areas of the leaf are affected and are bounded by the edge of the lamina ; they extend to a length of 20 cm. and to a width from 1.8 to 3.0 cm., the outer portion—presumably the seat of infection—is translucent and may be lightly tinted a cream colour ; irregular, more or less concentric, zones of a darker buff colour occur around the translucent area, and each zone is more or less distinctly demarcated by irregular borders of a buff to dull brown colour.

Associated Fungus.

Sporophores of a species of *Marasmius* are borne on the under surface of the older portions of the affected area, and on that account have their stipes usually strongly recurved. They arise from a mass of mycelium formed beneath the epidermis adjacent to a vein. Hyphæ of the fungus occur within the xylem vessels. No mycelial thread has been found, but there is a strong resemblance between the sporophores of this fungus and those described by Petch [14 : p. 25] for *Marasmius scandens*, the cause of the local White Thread disease of Cacao.

There appears to be no doubt as to the pathogenicity of the fungus. No other organism of pathogenic importance was found on the areas effected, and indication of the Marasmius being causal seemed to the author to be sufficient.

The fungus is believed not to have been described hitherto; the following description is compiled from the scanty material available,—

PILEUS, pale cream, floccose, up to 2 mm. in diameter, thin, in section consisting of a somewhat loose reticulum of thin walled cells overlying the trama, conchiform, somewhat orbicular in young specimens, strongly convex, usually sulcate over the gills which may be absent or up to 5 in number white, sometimes forked, ventricose and adnate : no cystidia were found ;

STIPE, dark brown tending to become lighter at apex, flecked with white flocci, usually bulbous at base, more or less hollow at maturity, usually strongly recurved, 1.0 to 1.25 by 0.12 mm ;

SPORES, hyaline, smooth, ovate, apiculate, 6 to 8 by 5 microns ;

ON foliage of *Zea mays* L., Bunso and Asuansi.

OTHER FUNGI ON MAIZE FOLIAGE.

A large number of fungi usually occur on the diseased, or dead, areas of maize leaves, the original cause of disease being obscured by their presence. The parasitism of some of the organisms may be doubtful, but their occurrence is considered to be worthy of record in the absence of more exact knowledge.

Phoma zeicola El. *and* Ev. (Plate VIII, fig. B) occurs with other fungi on withered leaves collected at Attabubu and Esiama, and developed in damp chambers on mouldy glumes of staminate inflorescences from Odumase and Asuansi.

PYCNIDIA, scattered, olivaceous-brown to black, spherical, submersed, erumpent by shortly beaked ostiole, 80 to 200 microns in horizontal diameter ;

SPORES, hyaline, 2 to 6 by 1.5 to 2 microns, cylindrical, extruded in mucous tendrils.

Cladosporium herbarum Link, causes a velvety, greenish-grey mould on dead portions of leaves at Ejura and elsewhere.

SPOROPHORES, olivaceous-brown usually pale at apex, septate, erect, frequently keeled, arising from stromatic mycelium, 4 to 110 by 40 to 7 microns, bearing short, sometimes branched chains of spores either apically or laterally;

SPORES, hyaline to light brown, subcylindrical to ovate, either continuous or 1 to 3 times septate, 5 to 18 by 3 to 6 microns.

Clasterosporium maydicum Sacc. (Plate X, fig. B), occurs fairly frequently on the withered portions of leaves in pure colonies surrounded by other fungi, at Aburi, Ejura and elsewhere.

It is recorded under the above name because in its early stage it agrees with Saccardo's diagnosis [17]. Its mature spores are, however, frequently muriform, a fact which makes its position in that genus doubtfully tenable, and one that Saccardo appears to have overlooked, since examination of No. 217 of Baker's Fungi Malayana determined as *C. maydicum*, and which may be taken as authentic material, shows similar muriform spores. A camera lucida drawing of that exsiccatum has been reproduced on Plate X under figure A for comparison with one of the local fungus (fig. B).

SPOROPHORES, short, hyaline, simple, solitary, arising from sub-epidermal mycelium, bearing one spore apically ;

SPORES, muricate, at first cylindrical to sub-globose, becoming ovoid to ellipsoid minutely spinulose, with 3 transverse septa, the second or third cell, frequently being divided again by a vertical septum.

Nigrospora sphaerica (Sacc.) Mason in lit.* (Plate X. figs. E. F), has been found on translucent leaf-spots with a diffuse light-brown border at Aburi, and with many other fungi on diseased areas of leaves, such as is shown by figure C of Plate I, at Aburi and Kumasi.

It has been given the above new combination with an extensive synonymy by Mason, who differentiates it from *N. oryzae* (B. & Br.) Petch on account of its larger spore dimensions. He states that cultures of the local fungus match well in size of spores the description of American mycologists of their *Basisporium gallarum* on maize.

Durrell [6] attributes a serious dry-rot of maize to *B. gallarum*, the spores of which average 13 to 18 microns in diameter. In 1923 in the State of Iowa the fungus effected a diminution in the germination of seed sown, and rotted the shanks, husks and stalks of mature plants, the damage done to the crop varying from 9.1 to 50 or 60 per cent. in some fields.

The fungus is not definitely known to cause serious disease in this country, but it is obvious that further investigation on this point is desirable.

The fertile hyphæ of *N. sphærica* are shown in figure F, Plate X arising from the stomata of a translucent leaf spot ; figure E of the same plate depicts the fungus as developed on cassava mush agar from the same source.

SPOROPHORES, oblong to ampulliform, 7 to 13 microns in width, hyaline to light-brown, bearing a single apical spore, arising apically or laterally from a fertile hypha of usually swollen segments ;

SPORES black, opaque, spherical in horizontal plane, flattened at base, somewhat pointed at apex, 15 to 20 microns in diameter.

*Published at time of going to press, by E. W. Mason, in Trans. Brit. Myc. Soc., p.158, as *Nigrospora sphaerica* (Sacc.) comb. nov.

Papularia sphærosperma (Pers.) v. Höhnel (Plate X, fig. C), occurs on withered areas of leaves in association with other fungi at Aburi, and has been recorded with no data in a collection made locally by W. H. Johnson under *Coniosporium arundinis* (Corda) Sacc.

It is probably merely saprophytic. Spores and their germination are shown in figure C. of Plate X.

SPOROPHORES, hyaline, straight, simple;

SPORES, lens-shaped with flattened margin, 10 by 5 microns, dark olivaceous brown, margin appearing in full face view as a paler and more or less translucent zone, and in profile as a translucent band dividing the spore into two plano-convex, darker, portions.

Epicoccum neglectum Desmaz. is recorded on dead portions of leaves collected at Ejura [30. Plate VII.].

SPORODOCHIA, black, pulvinate, arising from stomata of host in a manner suggesting that of the sori of *Hemileia*; .

SPORES, borne terminally on short, stout sporophores, at first oblong to clavate and non-septate, becoming globose, longitudinally septate, then muriform, constricted at septa, brown, somewhat obscurely areolate, 15 to 20 microns in diameter.

DISEASES OF MAIZE INFLORESCENCES AND GRAIN.

Apart from the affection of both staminate and pistillate inflorescences caused by *Ustilago zeæ*, the following diseases affecting the reproductive organs of maize occur locally.

MOULDY TASSELS.
(Prob. Ophiobolus heterostrophus Drech.)

In the damper districts of the maize area there are frequently found male inflorescences, the spikelets of which are matted together by a velvety, greenish-black mould. Figure D. of Plate I shows this condition as compared with normal spikelets. The attack may be sufficiently severe to affect the whole panicle, or only a few spikelets may bear the disease.

Examination shows a heavy infection on the surface of the glumes of a species of *Helminthosporium* which is considered to be the conidial stage of *Ophiobolus heterostrophus* Drechsler. Spores and sporophores from such material are depicted under figure B of Plate V, and others, cultivated on tap-water agar from the same source, under figure D. They do not appear to offer any morphological differences from those of the fungus discussed on p. 14 under Leaf-Spot of Maize.

In most cases that have been examined the stamens have been affected, and their function destroyed by the fungus, so that the damage done by the disease may be considered to have a direct result on yield in proportion to its incidence. The fungus is sometimes accompanied by *Acrothecium lunatum* (p. 16), and by *Phoma zeicola* (p. 23) on mouldy tassels. The disease has been recorded at Aburi, Asuansi, Odumase, Bunso and observed elsewhere.

EAR-ROTS.

A number of fungi are usually found on the dry rotted ears of maize in this country, of which *Diplodia macrospora* Earle described on p. 21 is no doubt pathogenic. In the United States of America, in addition to the ear rot caused by *Basisporium gallarum*, there is a complex group of diseases, comprising root, stalk and ear rots, attributed to a number of fungi that are found on affected material either singly or in combination; they are variously referred to by different workers as *Diplodia zeæ, D. macrospora, Oöspora verticillioides, Fusarium moniliforme, Gibberella saubinetii, Cephalosporium acremonium, and C. sacchari,* and it is alleged, cause more serious damage to maize than any other pathogens in America.

Until more exact investigations have been made locally the relationship between some of the above species that occur here and their effect on the host-plant cannot be definitely stated. The followings notes on their occurence, however, may be useful in indicating lines of future work.

Diplodia Macrospora Earle

As previously stated (p. 22) this fungus is considered by some workers to be a form of *D. zeæ*. It is recorded as an ear-mould of maize that caused heavy damage to the 1923 crop in Florida. A number of cases have been observed in this country, and the organism is described herein on p. 21.

Symptoms.

The illustration (fig F) of an ear-rot on Plate I is that caused by this species. Development of the cob has been arrested, the husks have prematurely withered to a straw colour, and show as a distinguishing character, the minute, but macroscopically visible, black dots caused by the development of pycnidia. In the case of later infections the trouble may not be apparent until the cob is dehusked when a white to greyish mycelium is found massed between the grains.

Effect.

Not only is there a direct loss of crop due to the destruction of ears or grains, but there is a strong suspicion that the mycelium (as is the case of *D. zeæ* in America) permeates the grain and causes loss to the succeeding crop. Moreover *D. zeæ* has been shown to cause paralysis to cattle fed on affected material in S. Africa.

The disease as caused by *Diplodia macrospora* has been collected at Juaso and Ejura.

Gibberella moniliforme Wineland.

There appears to be no doubt that this pathogen occurs here in its conidial stages. Miss Wineland [28] has shown that its microconidia agree in morphological characters with the fungus to which Saccardo gave the name *Oöspora verticillioides*, and that macroconidia, to which Sheldon's binomial *Fusarium moniliforme* should be applied, belong to the same organism. The ascigerous stage does not occur in nature and has only been observed in cultures of mixed strains.

Cultures inoculated in the field from Maize Leaf-spot II, were contaminated by a mould which when separated out and planted on maize seedlings gave typical macroconidia (illustrated under the name *Oöspora* sp. in fig. D, Plate VIII, of [30]).

Macroconidia of a *Fusarium* taken from a rotting maize culm, when used to inoculate a maize seedling also developed the characteristic microconidial stage [l.c. fig. E]. Sub-cultures from both sources have remained distinct, and the evidence afforded by this incomplete investigation is too inadequate to be of value.

Symptoms.

A fairly dense whitish mycelium occurs between the husks and generally infests the ear, while the stalk may or may not be rotted and the leaves withered. A great deal of work on the symptoms and etiology of this group of diseases is necessary before anything of authoritative value can be written on their local significance.

Associated Fungi.

The Fusarium spores measure 30 to 45 by 3 microns, and are from 3 to 5 times septate. The microconidia are borne on simple branched conidiophores which taper gradually to their apices, the spores being hyaline, usually obovoid, basally pointed, from 5 to 13 microns in length, and occurring in chains, or clustered, at the apex of the conidiophore.

EAR-ROT CONTROL.

It is suggested that any attempt to control the development of fungi causing rots in maize should include seed disinfection by heat; seed selection; a 4 to 5 years rotation, and efficient cultivation.

BLACK GRAIN.
(Botryodiplodia theobromæ Pat.).

An unusual affection of harvested ears was observed at Kumasi in 1926 during the dehusking of a crop of Hickory King maize that had been grown on a plot adjacent to cacao. A few cobs were found in which occasional jet-black, or greenish-slatey coloured grains

were interspersed, in groups of one to three, among those of normal colour. The affected grains were normal in shape, but the lighter coloured ones bore a few, scattered, shiny black protuberances on their lateral faces. Examination of a section through the cob revealed a blue-grey discolouration concentrated at the cut end and decreasing in intensity toward the apex of the pith. No sign of disease is said to have been noticed on the husks.

Mycelium typical of *Diplodia,* occurred in the discoloured pith and permeated the affected grains. The sub-epidermal fructifications, of roughly two millimetres diameter, were found to be pseudostromatic, consisting of similar hyphæ, and containing numerous, irregularly shaped, pycnidia, with internal dimensions of about 200 microns diameter and 500 microns height.

The spores, which at first were hyaline, continuous, oblong to oval in shape, were at maturity dark brown, once septate, measured 25 to 34 by 15 to 18 microns, and did not differ from those of *Botryodiplodia theobromæ* Pat. found on cacao.

Cacao pods, inoculated by incision with the mycelium either directly from black grains or from cultures, produced typical Diplodia pod-rot in about a week, and frequently, the fructifications of *B. theobromæ.*

It was apparent that infection of the ear had occurred at the cut surface of the shank.

C.—DISEASES OF GUINEA CORN.

So far as the author is aware the botanical position of this host-plant, or plants, has not been definitely determined. It is possible that several species that are now considered distinct [31 : p. 801], occur locally, and have in the past been grouped under the old binomial *Andropogon sorghum* Brot. (*Sorghum vulgare* Pers.)

As a crop Guinea corn or sorghum is not so extensively cultivated in the Gold Coast Colony as in the Northern Territories and some districts of northern Ashanti. For this reason its diseases have not been so closely observed as have those of maize. Of such as have been recorded, the grain-smut is probably the most destructive, many of the foliar diseases attacking only such leaves as have fulfilled their function.

GRAIN SMUT.

(Sphacelotheca sorghi (Link.) Clinton).

This disease did extensive damage to a large farm of Guinea corn at Ejura in 1924, and is said always to be present in that district, it has also been received from the Northern Territories.

Grain smut is recorded for practically all countries where the host crop is cultivated, and causes considerable losses, for example it is estimated to destroy annually in the State of Kansas, grain to the value of $2,000,000, and Butler [2 : p. 210] states that the value of the grain lost annually in India must amount to several millions sterling.

Symptoms.

The characteristic feature of Guinea Corn grain smut is the replacement of individual grains by spore sacs which, in all cases seen, consists of elongated, oval, greyish-black sacs full of dark coloured spores and enclosed by the normal glumes of the host-plant. Two smutted grains are illustrated (natural size) under figure B of Plate XI. Under the same figure may be found a section through one of the grains, enlarged four times, to show the columella that consists of tissue of the host-plant and persists after the dispersal of the spores.

Infection.

It is apparent that by the rupture of a spore sac a large number of spores are liberated which by attachment to grain subsequently used for seed, are potential pathogens.

Infection of a new host takes place immediately after the germination of the seed, and is said chiefly to occur by the mesocotyl. No visible effect of the presence of the fungus appears

until the ears are formed. Kulkarni [7] has shown in India that atmospheric temperature at the time of the germination of Sorghum seed is an important factor in determining the incidence of grain smut; by laboratory tests and field experiments using seed mixed with spores he obtained negative results at temperatures ranging from 36° to 40°C, and over 50 per cent. infection at a temperature of 25°C. Butler [2 : p. 210] also states that the optimum temperature for the germination of the spores of *Sphacelotheca sorghi* is from 20° to 30° C, and that although they may maintain their vitality for some years if kept dry, they germinate readily in moisture.

It is improbable that infection takes place by spores left in the soil from a previous crop unless a continuous spell of sufficiently dry weather has prevented their germination.

Control.

The facts that infection occurs only at the germination of the seed, and that it is usually caused by spores adhering to the seed, make seed disinfection particularly successful in dealing with this disease. Soaking the seed in a 2 per cent. solution of copper sulphate for 10 to 15 minutes, or in a $\frac{1}{2}$ per cent. solution of formalin for 1 to 2 hours with subsequent rapid drying, are advocated as effective methods.

Causative Fungus.

The spores of *Sphacelotheca sorghi* may germinate either by a promycelium of four cells each bearing a spindle-shaped sporidium, or directly by a branching germ tube, or by intermediate methods. The sporidia may produce either germ tubes or long branching chains of secondary sporidia. Infection is accomplished by the entry of a fine hypha produced either by a sporidium, or by the promycelium of a spore, and a mycelium is formed at the growing point of the seedling. When the ear begins to form the mycelium concentrates in the immature ovary, forms the membrane of the spore sac, and gives rise internally to the spore mass. The spores are frequently united in masses which break up into individual spores upon the application of water.

SORI, produced, within the immature ovary of the host, elongated into an oval or conical, greyish, spore sac of about 10 by 4 to 5 mm. dimensions, surrounded by the normal glumes of the host;

SPORES, round, smooth, dark brown to black in mass, olivaceous brownindividually, 6 to 8 microns in diameter.

IN the ovaries of *Andropogon sorghum* Brot. Ejura and the Northern Territories.

RUST.

(Puccinia purpurea Cke.)

The disease is usually prevalent on the older leaves of Guinea corn at Ejura. It is very generally distributed, and frequently

reported as the commonest rust disease of cultivated crops, in those countries where sorghum is grown. There is, however, some doubt as to the amount of loss it causes.

Symptoms.

In common with other pathogens which affect the leaves of sorghum, *Puccinia purpurea,* by causing the death of host tissue in its immediate neighbourhood, produces a reddish purple change in the normal colouration of the plant juices. These areas of discolouration, although small, may by their quantity cover a considerable area of the affected leaves. Small, somewhat elongated, brown pustules are produced chiefly on the under side of the leaf, either scattered or in groups.

Causative Fungus.

Puccinia purpurea Cke. (*Uredo Sorghi* Fckl. not *P. sorghi* Schw.) is said to occur on other hosts, including *Andropogon halepense,* and it is possible that the *Puccinia* sp. on *Andropogon gabonense* Stapf. illustrated under fig. E of Plate IX may prove to be this species.

Only the uredinial stage of *P. purpurea* has been observed on Guinea corn material from Ejura. The sori, which are rarely more than one millimetre in length, are at first covered by the epidermis of the host and are occasionally found to be parasitised by *Darluca filum.*

UREDOSPORES,	ovate or elliptic, yellowish brown, 37 to 45 by 26 to 32 microns indistinctly spinulose;
PARAPHYSES,	irregularly clavate, light brown, frequently contorted, with walls, up to 11 microns thick at apex.
ON	foliage of *Andropogon sorghum*, Ejura.

LEAF-SPOTS OF SORGHUM.

I.—(Colletotrichum andropogonis Zimm. [29 : pp. 13–15.])

Of the two common leaf-spot diseases, which differ from Sorghum rust in not being pustular, that caused by the above parasite may usually be differentiated by the small size and discrete occurrence of its reddish-purple spots.

The disease is prevalent on old leaves, but does not appear seriously to effect the yield of grain owing to late infection.

Causative Fungus.

It is probable that *C. graminicolum* (Westd.) Wilson is synonymous with Zimmermann's species ; the spores and a seta of the local fungus are figured on Plate VIII. fig F.

SPORES,	falcate, hyaline, 23–28 x 4–5 microns
SETAE	cylindrical, bulbous at base, rounded at apex, dark-brown almost hyaline at apex, septate, 140 x 5 microns.
ON	foliage of *Andropogon sorghum*, Ejura.

II.—(Cercospora sorghi E. and E.)

The tendency of Cercospora infections on Guinea corn foliage to elongate from small, purplish-red spots, and to coalesce, until an affected leaf presents but small and inconsiderable areas of normal coloration, is probably of greater diagnostic value than is the somewhat darker and duller discoloration produced by this fungus when compared with the effect of *Colletotrichum andropogonis*. The spots as they increase in size develop a clearly defined, buff or straw coloured, central portion which may be up to 9 cm. in length and 3 mm. in width, with a dull, dark purplish red, rather wide, border.

The disease occurs on old foliage in such profusion as to provide the source of a dye for some of the natives of the Northern Territories. Its effect on young plants is said to be almost negligible.

Causative Fungus.

Reference to figure C. of Plate VIII (drawn from Guinea corn leaf spots) shows short, 1 to 3 septate, spores that approximate to those of *C. Köpkei Krüg.*—a species recorded only for *Saccharum* sp.—together with longer, up to 7 times septate, spores which are in closer agreement with the description of those of *C. sorghi* E. and E. Both forms have been found to occur on the same spots on Guinea corn, and on similar spots on *Andropogon halepense*. Prof. Ashby (in lit.) has also recorded both forms as occurring on *A. sorghum* in Uganda. It is probable that both the shorter and the longer spores should be regarded as *Cercospora sorghi*, but neither has been subjected to cultural tests, nor is the degree of affinity between that species and *C. Köpkei* known.

SPOROPHORES, geniculated, hyaline when young, becoming fuscous later, 20 to 80 by 3 to 6 microns.

SPORES, tapering abruptly at base to a conspicuous hilum and gradually toward apex, straight or curved, hyaline, 1 to 7 times septate 20 to 84 by 2 to 6 microns.

ON leaves of *Andropogon sorghum* and *A. halepense*, Trom, Somanya, Ejura.

MOULDY INFLORESCENCES.

Mature inflorescences of Guinea corn have been found bearing copious growths of the fungus described under *Acrothecium lunatum* Wakk. (p. 16).

The occurrence is regarded as symptomatic of uncongenial conditions rather than as the actual cause of disease. An apparently similar condition is recorded for *Acrothecium lunatum* on Sorghum in the East, where it is likened to that caused by *Cladosporium*.

No noteworthy difference was obvious between the organism on this, and on other, host-plants found locally.

D.—DISEASES OF BULRUSH MILLET.

As is the case in Guinea corn, the local diseases affecting Bulrush Millet (*Pennisetum typhoideum* Rich.) have not been closely observed owing to the fact that the crop is but rarely cultivated in the forest areas of the Gold Coast. As a crop the host-plant does not appear to be so universally cultivated as other cereals, and consequently fewer diseases are recorded; Butler [2 : p. 218-226] gives three for India, the smut, green-ear disease, and rust, to which reference is made below.

SMUT.

(Tolyposporium penicillariæ Bref.)

The occurrence of bulrush millet smut in this country has been recorded for Tamale and Ejura, and occurred recently on a few plants grown, for experimental purposes at Aburi, from seed obtained at Ejura. At the latter place it is known to have caused a loss, of about one third the number of harvested ears on a small plot in 1926, and may be considered as a serious disease likely to increase in severity by the indiscriminate use of seed taken from diseased ears.

Butler stated in 1918 [2 : p. 224] that " outside India, it has not been definitely identified but appears to occur in Egypt and possibly in other parts of Africa ".

Symptoms.

The disease is readily detected by the presence of smutted ovaries which may be scattered either singly or in small groups, and are distinct from the normal grains by the bright green, brown or black colour of their membrane and by their longer development which projects them beyond the surrounding glumes. These grains are composed of a pear-shaped or oval sorus of brown to black masses of spores enclosed in a hypertrophied membrane of host tissue. Figure D of Plate XI shows two affected grains in situ drawn natural size; in immature ears, the symptoms of smut are more distinct than in those shown, individual infections being sharply demarcated from the background of undeveloped fruits by the conical bright green to black, projecting sori.

Causative Fungus.

Tolyposporium penicillariæ resembles the smut referred to on p. 29 as affecting Guinea Corn in its effect upon individual florets, but differs from that fungus by bearing its spores in tightly compacted masses that do not readily break up in water, and by having no columella.

McRae [9] reported in 1922 that the mycelium had been found in apparently healthy grains occupying the scutellum and seed-coat near the embryo. So that it is apparent that the disease is carried by the seed. Control measures should therefore consist of the selection of seed derived from known healthy parents, and seed disinfection by hot water should be attempted.

SORI, produced within the ovary of the host, pear-shaped to oval with conical or rounded apex, up to 6 microns in length by 4 microns wide, enclosed in bright green to dull black membrane.

SPORES, compacted in masses, 80 to 100 microns in diameter, round or angular with a light brown, thick wall irregularly roughened on free surface; 8 to 11 microns in diameter.

IN the hypertrophied ovaries of *Pennisetum typhoideum*, Ejura and Tamale.

SUGARY DISEASE.

(Sphacelia sp.)

Two mature ears of Bulrush Millet were received from Tamale in 1925, which bore, scattered among the normal grains, dried, black, sticky exudations that had apparently arisen from infected ovaries. Capt. Beal—to whom the author is indebted for the material—described the disease as " a kind of smear spread over the outside of the millet head ", and stated that " the natives attribute toxic properties to this parasite; they say that, when millet thus affected is ground into flour and eaten, it tastes sweet like honey, and then it causes the stomach to swell and also makes a person feel drunk. "

The disease occurs in Tanganyika where it is known as " Asali ", and is probably the condition to which Zimmermann referred in 1904 [29: p. 16] as an undetermined sclerotial growth in the ovaries of *Pennisetum spicatum*, such as precedes the development of a *Claviceps*.

The fungus has also been recognised as occurring in the South Kordofan district of the Sudan.

Causative Fungus.

Sphacelia sp. stromata occupying the position of grain are shown (natural size) in figure E of Plate XI. Such as have been examined were found to be somewhat longer than the mature grains, they were more or less conical in shape, convoluted externally, and bearing on the surfaces of the folds simple conidiophores arranged in palisades with single-celled, hyaline spores. The

stromata occasionally included stamens and other floral organs of the host either embedded in their tissue or closely adherent by means of a sticky exudation, which was also in some cases infested by a *Cladosporium* sp.

It is possible that the fungus may be identical with the *Sphacelia sorghi* of Indian mycologists, the cause of Sugary disease of Sorghum. Attempts to obtain the ascigerous stage by cultural methods have not been successful, and it is therefore impossible to arrive at a critical determination. Small [19 : pp.15-16] reports the occurrence of a *Sphacelia* on the ears and stems of *Pennisetum typhoideum* and *P. purpureum* Schum. in Uganda, which differs from that now under discussion by its larger, woody stromata, and is probably identical with the fungus described on p. 42 as a Sphacelia sp. on *Andropogon Gayanus* var *bisquamulatus*.

SPOROPHORES,	simple filiform, bearing a single spore apically.
SPORES,	hyaline, oblong tending to boat-shape, containing several oil globules, 11 to 22 by 2.5 to 4 microns;
IN	hypertrophied florets of *Pennisetum typhoideum*, Ejura and Tamale.

GREEN EAR DISEASE.

(Sclerospora graminicola Schroet.)

This disease has been reported as affecting bulrush millet in the Northern Territories, where it is said to be common on individual plants though never to assume epidemic proportions.

It occurs in India and East Africa, and the causal fungus is pathogenic to other host-plants of economic importance in Europe, India and the United States of America.

Symptoms.

The effect of the parasite upon the ears of an affected plant is strikingly conspicuous, somewhat suggesting to casual observation the effect of general vivipary; the ear is converted from the normally compact spike of flowers or grain into a loose, green, head of small, twisted leaves.

The presence of the fungus may also be indicated by white or brown, elongated areas in the leaves of the host.

Causative Fungus.

As in other species of the genus *Sclerospora*, the sporangial stage of *S. graminicola* Schroet. is evanescent, and is succeeded by abundant production of oöspores. These spores have highly resistant walls, and it is thought probable that it is by them that the parasite is carried over from one growing season to another in spite of the fact that efforts to induce their germination by laboratory methods are reported as unsuccessful.

Control.

It is suggested that a sufficient control of green-ear disease can be maintained by the eradication and destruction of infected plants.

RUST.

(Puccinia penniseti Zimm.)

A rust occurred in profusion on a few plants of *Pennisetum typhoideum*, grown for experimental purposes at Aburi in 1925. The facts that the disease has not yet been recorded for the source of origin of the seed, and that its only occurrence was on old and weakly developed plants which were grown under conditions not considered as ideal for the crop, do not indicate that it is a serious trouble. Its occurrence is of interest, however, as it does not appear to have been previously recorded for West Africa, nor for any other countries than India and East Africa.

Symptoms.

Small, elongated, pustular spots of an orange colour occur chiefly on the upper surface of the leaves, and on the stems, and assume a powdery appearance by the discharge of uredospores, later teleuto-sori are formed similar to those of the uredinial stage, except that they are from brown to nearly black in colour.

Causative Fungus.

Puccinia penniseti Zimm. (Plate IX, fig. A).

AECIDIAL STAGE	not known.
UREDINIAL STAGE,	sori amphigenous, numerous, sometimes confluent, pustular; spores oval or pear-shaped, yellow, spinulose, 28 to 41 by 23 to 30 microns, borne on hyaline stalks, 20 to 32 by8 to 10 microns ;
TELEUTOSPORES,	cylindrical to elongated oval, basal cell being much the longer, round or flat at apex, restricted at septum, with apically thickened wall, orange brown, smooth, 46 to 70 by 20 to 25 microns, borne on short, usually colourless stalks, 18 to 30 by 8 to 10 microns ;
ON	foliage and stems of *Pennisetum typhoideum* Rich., Aburi.

LEAF SPOT.

(Helminthosporium sp.)

Irregular spots 10 to 40 mm. in length, at first sepia in colour, becoming translucent with a narrow brown border and up to 11 mm. in width, have occasionally been found on bulrush millet at Aburi. When young the spots are coated on both surfaces by a velvety outgrowth consisting of brown sporophores.

Associated Fungus.

The unidentified species of *Helminthosporium* shown under figure E of Plate VII occurs on these spots. It produces from a somewhat torulose mycelium, simple sporophores in groups of one to six through the stomata. No ascigerous stage was found.

SPOROPHORES,	cylindrical, 2 to 5 times septate, brown with hyaline apex, up to 150 microns in length and 5 microns in width ;
SPORES,	ellipsoidal, tapering more abruptly to proximal, than distal, end, straightor slightly curved, fuliginous, 6 to 12 times septate, 38 to 122 by 13 microns ;
ON	leaves of *Pennisetum typhoideum* Rich.,Aburi.

E.—DISEASES OF RICE.

Rice, although imported in considerable quantities, is not generally grown as a staple food-crop on the Gold Coast: except for certain parts of the Northern Territories, and the south-western district of the Colony, the crop only occurs in isolated patches where it is cultivated by settlers from other countries.

Such diseases as are known to occur locally are not usually serious—a possible exception being those caused by *Piricularia oryzæ*.

BLAST.

(Piricularia oryzæ Br. and Cav.)

In 1922 the rice crop at Adebrem was threatened with considerable loss by the occurrence of the above fungus which is known in other countries as the cause of this destructive, and sometimes epidemic, disease; the attack was, however, checked by a dry spell of weather and has annually recurred with varying amount of damage. It has also been collected subsequently at Asuansi, Juaso and Ejura. Its presence was usually apparent in connection with leaf-spots, but at Essiama it has more recently been found on the upper part of the stem resulting in the destruction of the neck with consequent loss of grain.

The disease occurs universally wherever rice is cultivated, and has been known in Italy for many centuries; it is regarded as the most serious disease affecting rice.

Symptoms.

The evident effects of the presence of *Piricularia oryzæ* on rice plants may differ according to the severity of attack and to the age of the host at time of infection. Small brown spots, which develop into ashen grey areas of considerable size with an irregular brown border, occurring on the leaves, have up to the present been the most common manifestation locally. Natural recovery by tillering, consequent upon climatic conditions that were adverse to the development of the pathogen, has been observed in young plants, but, failing such conditions the effect of the fungus was more or less similar to that of malnutrition.

In other cases where infection had taken place later in the life of the host, the upper nodes of the stem, or the pedicels, were attacked, the affected areas being brown in colour and becoming shrunken by the destruction of internal tissue; such infections frequently resulted in the collapse of the head from the point of attack.

Control.

In the present stage of our knowledge regarding the life history of the fungus causing rice blast, no other measure to control the disease appears to be practicable than to provide the most favourable conditions for the vigorous growth of the host plant by cultivation and general sanitation methods. Local research is needed to ascertain how infection occurs, whether seed disinfection would provide an efficient and economical method of control, what other hosts of the parasite occur, and whether permanently resistant strains of rice could be obtained by breeding.

Causative Fungus.

Piricularia oryzæ Br. & Cav.) Plate VIII. fig. D. Small [19: pp. 16 and 17] by experimental work in Uganda ascertained that rice-blast can be caused by *P. oryzæ*, to which parasite the disease is usually attributed by other workers. The fungus is morphologically indistinguishable from *P. grisea* (Cke.) Sacc. a parasite on *Digitaria sanguinalis*, but from work in India [9] it would appear that the two specific names represent biological strains. No ascigerous stage of the fungus is known, but the viability of the conidia has been shown by Sundararaman [21] to be effective after 5 months of dry storage, usually a sufficient period to tide over a dry season.

SPOROPHORES,	pallid, usually simple, 2 to 5 times septate, about 120 by 4 microns arising in groups of 1 to 5 from the stromata;
SPORES,	obovate with distinct hilum, twice septate, 18 to 33 by 10 to 11 microns.
ON	leaves and stems of *Oryza sativa*, Adebrem, Essiama, Asuansi, Juaso, Ejura.

BROWN LEAF SPOT OF RICE.

(Helminthosporium oryzæ van Breda de Haan.)

A very prevalent disease on rice growing under unsatisfactory conditions has been found on one or two occasions in Ashanti and at Aburi. In one case a fairly large farm was examined and practically every leaf of the half-developed crop found to be heavily infected. In another instance, rice grown on land which had borne the same crop during the previous four years, showed abundant symptoms of the brown leaf-spot. Other collections have been made from rice grown in an unsuitable environment and from self-sown seedlings that had developed out of season.

The disease is said to be of universal occurrence, and to be particularly severe in its attack upon young seedlings—a mortality from 10 to 58% having been reported among seedlings in the Philippines for 1918 and 1919 [12], whilst in Japan the incidence of the disease may be so high as to make it difficult sometimes to find a seedling entirely free [4: p. 727].

Symptoms.

The leaf spots are at first minute and warm brown in colour, they increase in size principally in a longitudinal direction until they attain a length up to 4 mm; in this later stage they may become lighter or even an ash grey colour in the centre; in their early stage many show a tendency to irregular zonation. Sporophores are formed chiefly on the lower side of the leaf and tend to spread beyond the limits of the spots when the latter are sufficiently prevalent to cause the death of the intermediate tissue.

Control.

Ocfemia [12] states that the causal organism is carried over from one season to another as dormant mycelium on the seed, a fact which accounts for the good results obtained by workers in Japan in their attempt to control the disease by the hot water treatment of seed. Immersion for ten minutes in water heated to 52° C., or for five minutes in water at 54° C., after the seed has been soaked in water at atmospheric temperature for 24 hours has been recommended. It must be borne in mind, however, that the fungus has been proved to be infective to many other species of grasses, and that the sterilisation of seed without clean weeding might not be effective.

Causative Fungus.

Helminthosporium oryzæ B. de H. (Plate VII, figs. A-D). Van Breda de Haan described the fungus in 1900 as causing a leaf-spot on rice in Java, and Miyabe and Hori gave the same name to the same fungus in Japan in 1901. It has been confused in Italy with species of *Piricularia* and with other species of *Helminthosporium* as being one of the causes of the condition known as the brusone disease of rice.

As in some other species of the genus, the conidia differ considerably in size according to the substratum on which they develop, a fact which may be illustrated by a comparison of the spores shown under figures A, B, and D from leaf spots, with those figured under C from affected seed. No ascigerous stage is known.

The conidia upon germination adhere to the surface of their host by means of appressoria formed by the swelling and branching of the tip of the germ tube; from these structures infective hyphæ either penetrate the cuticle direct or enter by means of the stomata.

Ocfemia [13] found in the Philippines that the conditions favourable for the germination of rice seed and for the sporulation of the fungus were nearly the same.

SPOROPHORES,	brown to an almost hyaline apex, sometimes branched from the base, slightly constricted at the septa, inconspicuously geniculated, up to 350 by approximately 7 microns;
SPORES,	fuliginous, tapering towards a slender apex, rounded basally, with included hilum, curved, 55 to 108by 13 to 20 microns, 5 to 9 times septate; germination bipolar;
ON	the foliage of *Oryza sativa*, Ejura, Juaso and Aburi.

MOULDY INFLORESCENCES OF RICE.

(Helminthosporium oryzæ van Breda de Haan.)

Another manifestation of the activities of *Helminthosporium oryzæ* has been collected at Adebrem and Aburi, in which the panicles bear numerous, but scattered, spikelets that are conspicuously differentiated by the presence of dark brown spots of varying size.

No observations have been recorded as to the amount of crop lost by this disease, but the fungus has been found to infest all parts of a spikelet, with the result that empty glumes occur in a ripe head of grain.

The probable relationship of this affection with the brown leaf-spot also requires investigation, but the fungus, save for the facts that its spores (see Plate VII. fig. C) are of more generous dimensions (93 to 140 by 15 to 20 microns), and that they arise from a mat of superficial hyphæ, does not differ from the *Helminthosporium oryzæ* of the brown leaf-spot.

Acrothecium lunatum (Plate VI. fig. F.) sometimes occurs in association with the above fungus on mouldy rice spikelets, in the same way that it is found on similar affections of maize.

NIGROSPORA ORYZÆ ON RICE.

Scattered groups or single examples of the sporophores of *Nigrospora oryzæ* (*B.* & *Br.*) Petch have frequently been found during the examination of rice foliage for possible pathogens. The sporophores have sometimes been seen to arise through the stomata of apparently healthy material, and in none of the cases examined has definite evidence been found of the fungus being the cause of a pathological condition on rice leaves. On the other hand, the fungus has been found in one collection in abundance on all parts of immature rice spikelets strongly suggesting that its presence accounted for the barren heads. The glumes were discoloured either completely or by grey areas, whilst the withered reproductive organs were infested by a white to fuliginous mycelium bearing scattered spores.

Associated Fungus.

Nigrospora oryzæ (B. & Br.) Petch (Plate X, fig. D). Mason (in lit.)* gives an extensive synonymy for this species, including the smaller spored form of *Basisporium gallarum*.

Local examples are similar to the N. sphærica found on maize (see p. 24) but differ in having smaller spores which when young are lighter in colour.

SPOROPHORES,	oblong or ampulliform, fuliginous or hyaline, usually arising in groups from hyphae of short swollen segments ;
SPORES,	brown to black, spherical in horizontal plane, 10 to 18 microns in diameter ;
ON	leaves and spikelets of *Oryza sativa*, Aburi, Adebrem, Essiama.

*Published, at time of going to press by E. W. Mason in Trans Brit. Myc. Soc. XII, p. 160.

F.—DISEASES OF SUGAR CANE.

Sugar cane is not grown as a commercial crop in the Gold Coast Colony. It is planted in usually very small patches and used merely for local consumption in its raw state rather as a sweetmeat than as a staple article of diet.

The following diseases have been noticed.

RING-SPOT.

(Leptosphæria sacchari van Breda de Haan.)

This disease, common in practically all cane countries, occurs generally where the crop is grown. It attacks the older leaves, and whilst it is possible that some loss to the host may result, severe damage is infrequent.

Symptoms.

Small purplish-brown spots appear on the leaves usually toward the edge and extend to form long (3 by 1 c.m.), oval or acutely irregular, straw coloured spots with a markedly distinct border of purplish-brown. Frequently the affected areas of the leaf assume an orange-yellow discoloration in patches which tone off to normal green. The spots occur in large numbers and are visible on both sides of the leaf.

Control.

The disease is not considered of sufficient importance to warrant special preventive measures being adopted. It is said that some varieties of cane are much more susceptible to attack than others, and that moisture conditions predispose such varieties of cane to the disease.

Causative Fungus.

Leptosphæria sacchari B. de H. (Plate VIII. fig. H.) Fructifications of the fungus may be visible on the upper surface of an affected leaf as very small black dots on, or less frequently beyond, the spots; they are the perithecia shown in fig. H. of Plate VIII.

A conidial stage, of which the spores are described as curved and thrice septate, has sometimes been ascribed to this fungus as the actively infective agent. It is possible that the incidental occurrence on ring-spots of the fungus described on page 16 as *Acrothecium lunatum* accounts for this assertion.

PERITHECIA, spherical, light brown, thin walled, immersed, ostiolate 100 to 170 microns in diameter, scattered on upper surface of leaf;

ASCI, clavate, containing 8 spores in 2 or 3 rows.

ASCOSPORES, colourless or becoming light brown, 3 times septate, central cells wider than those at ends, constricted at septa, elongate straight, 18 to 25 by 5 to 7 microns;

ON leaves of *Saccharum officinale* L. at Aburi and elsewhere.

OTHER FUNGI FOUND ON SUGAR-CANE.

Helminthosporium sp. An undetermined species of *Helminthosporium*, the apparent cause of buff, elongated areas of discoloration, which measure up to 20 cms. in length and are surrounded by a narrow, purplish border, has been collected on young leaves of sugar-cane at Asuansi. The fungus differs from Butler's *H. sacchari* [2 : p. 408] by its much larger spores; it produces a black, mouldy appearance on the withered centres of the affected areas by the development of its sporophores which arise, frequently in pairs, from stromatic masses of dark mycelium.

SPOROPHORES, brown with hyaline apex, thick walled, geniculated, 6 to 8 times septate, up to 145 by 5 to 6 microns;

SPORES, fuliginous, straight or slightly curved, almost cylindrical, thickest at or below middle, tapering gradually to both ends, with conspicuous hilum, 7 to 11 times septate, 38to 148 by 13 to 16 microns with bipolar germination.

Acrothecium lunatum Wakk. occurred in profusion with the preceding *Helminthosporium* and presented no essential difference from the fungus described on p. 16. It is illustrated by Plate VIII, fig. B. of the G.C. Dept. of Agric's. Year-book 1926.

Nigrospora sphærica (Sacc.) Mason. This fungus, referred to on p. 24 as occurring on Maize foliage, has been collected on withered areas of sugar-cane leaves in small colonies. Its spores averaging about 6.5 microns in diameter preclude it from the larger spored *N. sacchari* (Speg.) Mason.

G.—UNCULTIVATED HOST-PLANTS.

Some of the following fungi found on wild graminaceous, or allied, host-plants are of interest.

ANDROPOGON GABONENSE STAPF.

This grass is commonly affected by a rust which is illustrated by figure E. of Plate IX. The fungus bears resemblance to *Puccinia purpurea* Cke. the causal organism of rust on several varieties of sorghum.

UREDOSPORES, light yellow, ovate, spinulose, 25 to 30 by 20 microns, accompanied by numerous, irregularly clavate paraphyses with much thickened apical cell-wall, 40 to 50 by 12 microns.

TELEUTOSPORES, red-brown, broadly elliptical, with rounded base and apex smooth, scarcely constricted at septum, wall uniform in thickness, 35 to 40 by 26 to 28 microns.

ANDROPOGON GAYANUS VAR. BISQUAMULATUS HACK.

The most interesting fungus found on this host is a sclerotial outgrowth that frequently occurs on the leaves or stem, and is considered to be a *Sphacelia*.

The earliest symptom of attack is the presence of insects and sooty moulds attracted to the affected parts by a saccharine exudation. A sclerotium, internally almost white with an external leathery, brown to black surface follows, and, usually by its development as a crescentic cushion, bends the leaf or stem into an acutely recurved position. The surface of the sclerotium is divided longitudinally and transversely by fissures into a number of rectangular, flat protuberances, thus presenting a muricate appearance. Sections through sclerotia at this stage usually show narrow, convoluted sinuses penetrating to half the depth of the sclerotia and filled with a mass of small (5 to 10 by 2 microns), hyaline, cylindrical conidia borne on simple sporophores.

Later in the year, light buff excrescences may develop on the sclerotium, and bear catenulate, thick walled, ovate, hyaline, apiculate spores which measure 10 to 14 by 8 to 10 microns, on simple clavate sporophores which are characterised by the thickness of their walls at the apical end, and by the abrupt, sometimes angular constriction at the usually elongated point of insertion; they measure approximately 50 microns in length by 7 microns at the upper end, and 4 at their base, in width.

It is possible that this fungus is distinct from those considered to be *Sphacelia*; it may possibly prove to be related to the genus *Langloisula*, published by Ellis & Everhart, in 1889 (Journ. Myc., 5, pp. 68-9).

ANDROPOGON HALEPENSE BROT.

The fungi referred to *Helminthosporium turcicum* Pass. on p. 12 as occurring in leaf blight of Maize, and to *Cercospora sorghi* E. & E. on p. 31 as causing a leaf spot on Sorghum, have both been found associated with leaf disease of this indigenous variety of sorghum.

IMPERATA ARUNDINACEA CYR. (LALANG).

A rust caused by *Puccinia rufipes* Diet. (Plate IX. fig. F.) frequently occurs on the older leaves of this weed.

UREDOSPORES, light yellow to brown, ovate to rotund, sometimes elongate, spinulose, with 4 germ-pores, 22 to 35 by 19 to 27 microns; paraphyses numerous, irregularly clavate or capitate, arising from slender base, with much thickened wall at apex;

TELEUTOSPORES, brown, elliptical to irregularly ovate, sometimes contorted, constricted at septum, smooth, 24 to 37 by 18 to 22 microns.

The uredosori of *Puccinia rufipes* on lalang are frequently parasitised by *Darluca filum* (Plate VIII, fig. E).

In some cases, an ascomycete with black, thin-walled, globose or papilloid, ostiolate perithecia, averaging 100 to 130 microns, has been found associated with *Darluca filum* in the sori. Its clavate, almost cylindrical asci, measure 52 to 74 by 8 to 10 microns, and contain eight hyaline, fusiform, bicellular, spores, which are constricted at the septum, usually less pointed at one end than the other, and are enclosed in a mucilaginous capsule. They germinate at each pole, and cases have been found in which germination had started before the spores were liberated from the ascus.

MELINIS MINUTIFLORA BEAUV.

The only parasite recorded locally for the recently introduced Efwatakala grass is an undetermined species of *Sclerotium*.

MARISCUS UMBELLATUS VAHL.

The inflorescences of this sedge are sometimes parasitised by a smut which usually affects the ovaries. The fungus agrees in essentials with those species of *Cintractia* that affect Cyperaceous hosts. It has somewhat, flattened, oblong to ovate, more or less angular, spinulose, light brown, spores that measure 10 to 12 by 7 to 9 microns, and is considered to be *Cintractia axicola* var. *minor* Clint.

PANICUM MAXIMUM JACQ.

Smut.

The ovaries of this indigenous fodder-grass are frequently infected by *Ustilago heterospora* Henn. (Pilze Ostafrika, p. 48.) The affection may be easily recognised by the green, hypertrophied,

ovaries of about 6 by 4 mm. in size, which take the place of normal florets in more or less profusion. The fungus is illustrated by figure C of Plate XI, and is widely distributed throughout Africa on this host. The smut pustules contain large numbers of short, usually three-branched, sporogenous hyphæ which, in addition to their normal function, appear able to form either sporidia by abscission or to develop hyphal outgrowths when placed in a nutrient medium. They are frequently dispersed with the ripe spores, and may serve as a secondary means of reproduction. The spores are light to dark brown, globose, with a thick epispore and vary from 9 to 20 microns in diameter.

Mouldy Inflorescences.

During wet weather the inflorescences of *Panicum maximum* are frequently affected by a *Fusarium*, which may, or may not, be associated with the above smut. Dr. Wollenweber, to whom the fungus was referred, considered it as a form of *Fusarium heterosporum* Nees on account of the carmine red colour of its stroma, and it may be cited as *F. heterosporum* Nees *forma one* Wollenwr. (lit.). The fungus is widely distributed on this host in Africa, and has been recorded as *F. paspalicola* Henn. Its spores are shown in figure *K* of Plate VIII.

F. heterosporum is recorded as affecting *Pennisetum typhoideum* on the Krobo Plains by a collection made by W. H. Johnson (No. 42.) in 1899.

Leaf Spot.

The *Phyllachora* which causes round to elliptical black spots up to 5 mm. in length, on either side of the leaves of *Panicum maximum* appears to agree with the description of *Phyllachora heterospora* P. Henn. *apud* de Wildeman [27 : p. 362] as revised by Theissen and Sydow (Anns. Mycol. XIII, p. 453-4, 1915). It is illustrated by figure J of Plate VIII, and may be described as follows :—

STROMATA, amphigenous, numerous, round to elliptical, about 1 mm. in diam. convex in transverse section, occasionally confluent, loculi fairly numerous, flask-shaped or distorted by compression, ostioles elliptical, 90 to 130 microns in width by 110 to 170 microns in height;

ASCI, cylindrical to clavate, with 8 spores arranged in two rows, 58 to 80 by 12 microns;

ASCOSPORES, hyaline, elliptical, with rounded ends, continuous, 12 to 15 by 7 to 9 microns.

(Johnson (No. 184) collected a *Phyllachora* on "Arundo?" in 1901, and recorded it as being near *Ph. graminis*. Only a scanty drawing of this collection remains which seems to indicate that the fungus may be referred to the above species.)

PENNISETUM POLYSTACHYUM SCHULT.

A fungus found to be infesting the ovaries of this host is illustrated by figure A of Plate XI. In appearance its effect resembles macroscopically that of a smut owing to the replacement of the normal organs by a brown to black stromatic mass. As is indicated by the drawing, the stroma is strongly convoluted; it consists internally of hyaline hyphæ with an external layer of dark, thick walled hyphæ which give rise to the superficial pedicillate spores. The latter are formed by a primary transverse division of the swollen apices of the pedicels, and become up to six-celled by subsequent division in any plane; each cell becomes irregularly globose, 5 to 11 microns in diameter, and at maturity is capable of germination.

The fungus agrees with the description of *Cerebella cenchroidis* Subram. [20: p. 206], parasitic on *Pennisetum cenchroides* and *Cenchrus biglorus* in India.

ROTTBOELIA EXALTATA L.

Rust.

Two collections from different localities have been made of a rust of this host-plant which might be regarded as *Puccinia Rottboeliæ* Sydow [22 p. 800], described as affecting *Rottboelia. arundinacea* (a synonym of *R. exaltata*) in Abyssinia, except that the apex of the teleutospores has not been found to be more than 4 microns in thickness, whereas in Sydow's species it may be up to 10 microns. It is possible that this character may prove to be variable as is indicated in Arthur's synonymy [1. pp. 176-8] for the closely related species—*Puccinia levis* (Sacc. & Bizz.) Magn.

The teleutospores of the local fungus are frequently inserted laterally as is shown by figure B of Plate XI. This again is a variable character and marks a transition to the genus *Diorchidium* Kalchbr.

UREDOSORI,	epiphyllous, scattered or in small longitudinal clusters, sometimes confluent, tawny (Ridgway 13′i) pulverulent, small, elliptical, surrounded by the longitudinally ruptured and incurved epidermis;
UREDOSPORES,	obovate to subglobose, spinulose, mustard yellow (Ridgway, 19′ b), 23 to 30 by 20 to 22.5 microns;
TELEUTOSORI,	epiphyllous, crowded, black, sometimes surrounded by purple (Ridgway 69′ k) areolæ elliptical to linear, hemispherical in section, 0.2 to 2 microns long, occasionally confluent, surrounded by the longitudinally ruptured epidermis;
TELEUTOSPORES,	ellipsoid to oblong, usually inserted laterally, apex rounded or occasionally elliptical, base rounded, rufous (Ridgway H′i), 30 to 39 by 19.7 to 23.4 microns, epispore smooth, 2.3 to 4.9 microns thick; pedicel persistent, hyaline, 78 to 180 by 3.8 to 5.5 microns.

Leaf-stripe. (*Helminthosporium sp.*)

The leaves of *Rottboelia exaltata* have sometimes been found to be affected by spots up to 5 cm. in length with buff coloured withered centres surrounded by a narrow brownish-purple border,

The spots bear on the under surface of the leaf a profusion of fuliginous, 2 to 4 times septate, cylindrical sporophores which measure up to 240 by 4 to 7 microns, and arise from the stomata in groups of one to four. They bear almost hyaline, thick walled, short ellipsoidal, spores which measure from 43 to 58 by 13 to 15 microns, and germinate at either pole.

SETARIA SULCATA RADD.

The conidial stage of an *Ustilaginoidea* occurs locally in the florets of this host-plant, and is illustrated on Plate XI by figure F. The sclerotia, which superficially resemble the effect of some of the smuts, are sub-globose, 3 by 2 mm., and composed internally of densely woven hyaline hyphæ. They are, at first, yellow and powdery owing to the production of large numbers of spores, but later become smooth and almost black externally. Those figured are in the earlier condition. The spores are spherical, bright yellow to olive green, somewhat tuberculate, 5 to 7 microns in diameter, and are borne by parallel fertile hyphæ on the surface of the sclerotium.

It is possible that the fungus may be referable to *U. ochracea* Henn. described as infecting *Panicum auritium* in the Phillippines and India.

The ascigerous stage has not been seen.

SPOROBOLUS PYRAMIDALIS BEAUV.

The inflorescences of this grass are commonly infected by *Helminthosporium ravenelii* Curt. The fungus, which is well known throughout the world where the host occurs, is illustrated by figures F & G on Plate VII. It produces a brown, velvety mass of branched sporophores on the floral parts of the host, and ultimately presents the appearance of a black, matted investment.

Another affection of the inflorescences of *Sporobolus pyramidalis* is caused by *Epichloë cinerea* B. & Br. and is shown in figure G of Plate VIII. In this case the inflorescence is compactly ensheathed by a stroma up to 8 c.m. in length by 2 mm. wide. The stroma is cream coloured but may appear to be brown owing to the number of purple-brown ostioles which protrude slightly from its surface.

The transverse section in the figure shows the flask-shaped, rather long necked, perithecia in which are produced the filiform, multiseptate ascospores.

UROCHLOA INSCULPTA STAPF.

An unidentified rust has been collected on this grass at Kumasi, and is shown on Plate IX, fig. C.

R. H. BUNTING,

Assistant Director of Agriculture
for Research and Senior Mycologist.

APPENDIX I.

SUMMARY OF LOCAL FUNGI DESCRIBED IN THIS BULLETIN.

Peronosporaceæ.

Sclerospora graminicola Schroet. on *Pennisetum typhoideum*.

Nectrieæ.

Gibberella moniliforme Wineland, on *Zea mays*.

Hypochytriaceæ.

Physoderma zeæ-maydis Shaw, on *Zea mays*.

Clavicipiteæ.

Epichloe cinerea Berk. and Broome, on *Sporobolus pyramidalis*.
Ustilaginoidea ?ochracea Henn., on *Setaria sulcata*.

Dothidiaceæ.

Phyllachora heterospora P. Henn., on *Panicum maximum*.

Pleosporaceæ.

Leptosphæria sacchari B. de H., on *Saccharum officinarum*,
Ophiobolus heterostrophus Drechs. (conidial stage only), on *Zea mays*.

Ustilaginaceæ.

Cintractia axicola (Berk.) Cornu var. *minor* Clin., on *Mariscus umbellatus*.
Sphacelotheca sorghi (Link) Clin., on Guinea-corn.
Tolyposporium penicillariæ Bref., on *Pennisetum typhoideum*.
Ustilago heterospora Henn., on *Panicum maximum*.
Ustilago zeæ (Beck.) Ung., on *Zea mays*.

Pucciniaceæ.

Puccinia maydis Béreng, on *Zea mays*.
Puccinia penniseti Zimm., on *Pennisetum typhoideum*.
Puccinia purpurea Cooke, on Guinea corn.
Puccinia rufipes Diet., on *Imperata arundinacea*.
Puccinia ? rottboeliæ Syd., on *Rottboelia exalta ta*.
Puccinia sp. on *Andropogon gabonense*.
Puccinia sp. on *Urochloa insculpta*.

Marasmieæ.

Marasmius sp. on *Zea mays*.

Sphærioidaceæ.

Botryodiplodia theobromæ Pat., on *Zea mays*.
Darluca filum, on *Puccinia*.
Diplodia mascrospora Earle, on *Zea mays*.
Phoma zeicola E. and Ev., on *Zea mays*.

Melanconiaceæ.

Colletotrichum andropogonis Zimm., on Guinea-corn.
Pestalozzia sp. on *Zea mays*.

Moniliaceæ.

Cephalosporium acremonium Corda, on *Zea mays*.
Piricularia oryzæ Br. and Cav., on *Oryza sativa*.

Dematiaceæ.

Acrothecium lunatum Wakk., on *Zea mays*, *Oryza sativa*, *Saccharum officinarum* & on Guinea-corn.
Cercospora sorghi E. & Ev., on Guinea-corn.
Clasterosporium maydicum Sacc. on *Zea mays*.
Helminthosporium oryzæ B. de H., on *Oryza sativa*.
Helminthosporium ravenelii Curt., on *Sporobolus pyramidalis*.
Helminthosporium turcicum Pass., on *Zea mays* and *Andropogon halepense*.
Helminthosporium sp. aff. *rostratum*, on *Zea mays*.
Helminthosporium sp. aff. *sativum*, on *Zea mays*.
Nigrospora oryzæ (B. & Br.) Petch, on *Oryza sativa*.
Nigrospora sphærica (Sacc) Mason, on *Zea mays*.,
Papularia sphærosperma (Pers.) van Höhn, on *Zea mays*.

Tuberculariaceæ.

Cerebella cenchroidis Subram. on *Pennisetum polystachyum*.
Epicoccum neglectum Desm., on *Zea mays*.
Fusarium heterosporum Nees forma *one* Wollenwr., on *Panicum maximum*.
Sphacelia sp., on *Andropogon Gayanus* Kunth. var. *bisquamulatus Häck*.
Sphacelia sp., on *Pennisetum typhoideum*.

Mycelia Sterilia.

Sclerotium sp., on *Melinis minutiflora*.

APPENDIX II.

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PLATE IV.

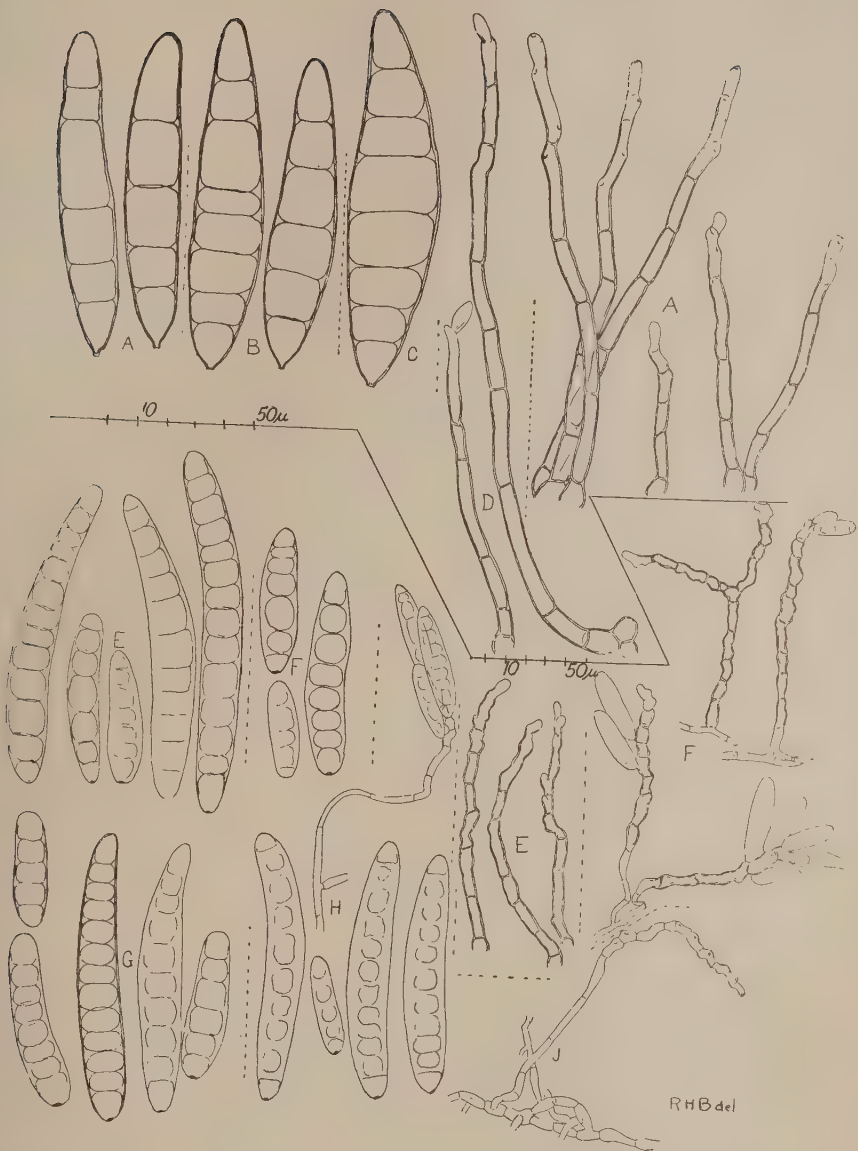
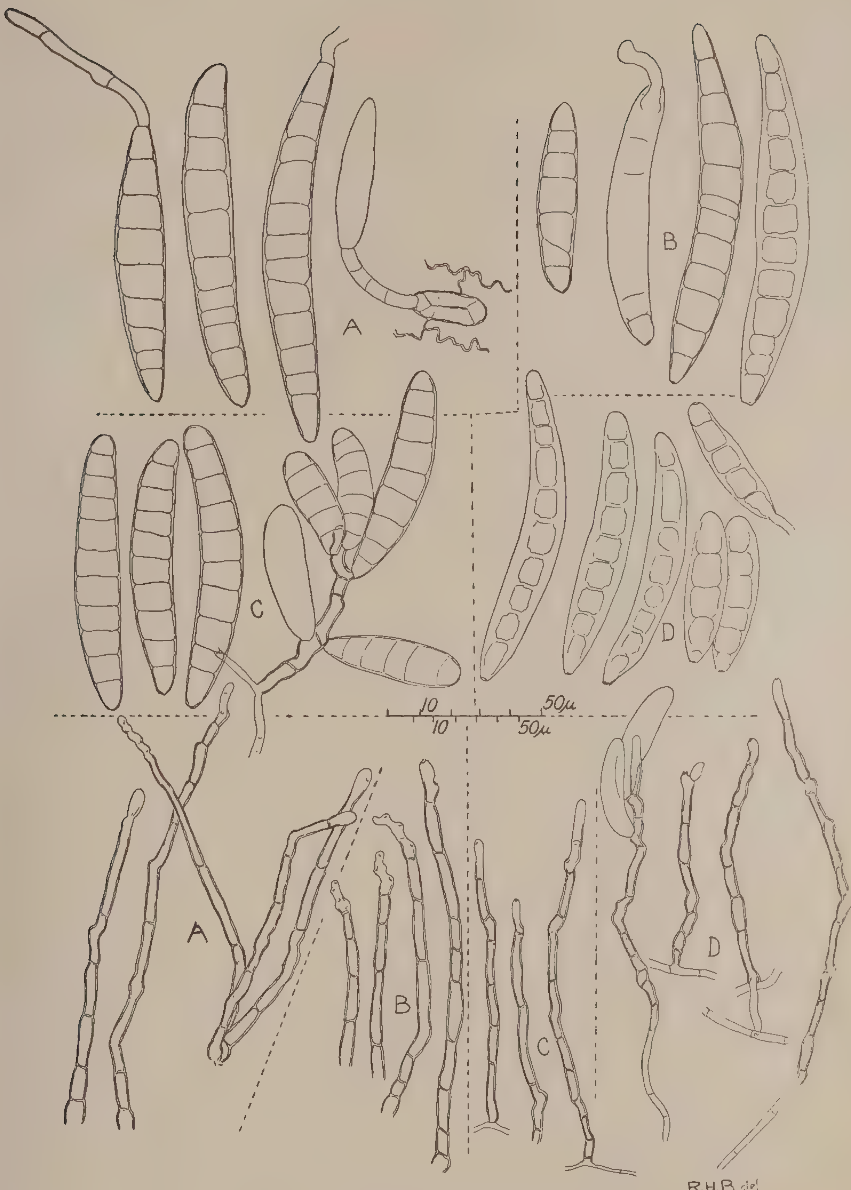


Fig. A.—*Helminthosporium turcicum* Pass. on Maize leaf, Aburi.
,, B. ,, ,, tap-water agar culture of A.
,, C. ,, ,, on Maize leaf, Krobo.
,, D. ,, ,, on leaf of *Andropogon halepense.*
,, E.—*Helminthosporium* aff. *sativum,* from mouldy patches on leaf-sheath of Maize.
,, F. ,, ,, ,, tap-water agar culture of E.
,, G. ,, ,, ,, occurring on blackened auricles of Maize.
,, H. ,, ,, ,, tap-water agar culture of G.
,, J. ,, ,, ,, tap-water agar culture from Maize leaf-spot II.

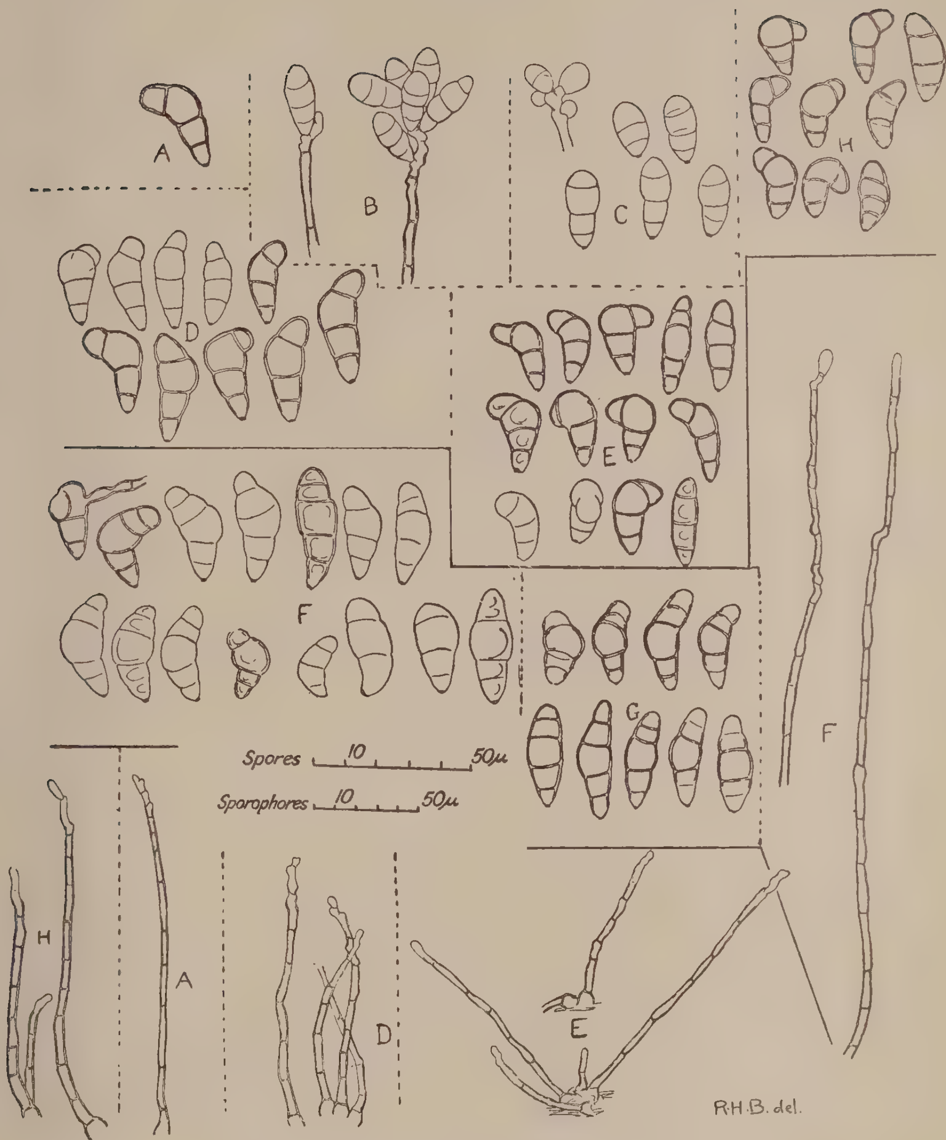
PLATE V.



Ophiobolus heterostrophus Drechsler, conidial stage.

Fig. A.—On Maize leaf, Aburi.
,, B.—On staminate inflorescences of Maize, Aburi.
,, C.—Tap-water agar culture of A.
,, D.—Tap-water agar culture of B.

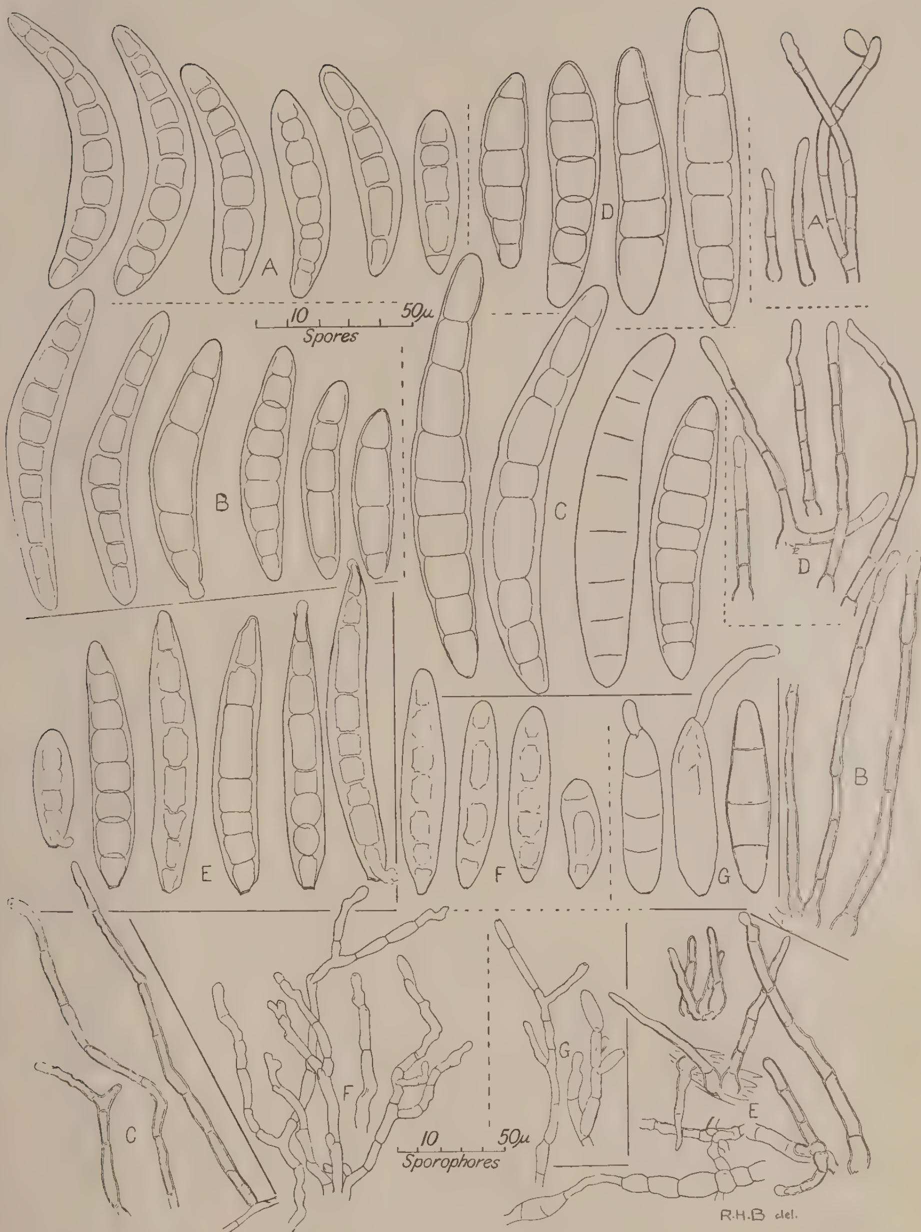
PLATE VI



Acrothecium lunatum Wakker sec. Mitra.

Figs. A and D.—On Maize leaf-spot II, Juaso.
Fig. B.—Tap-water agar culture of A.
,, C.—Cassva-mush agar culture of A.
,, E.—On Maize leaf-spot II, Aburi.
,, F.—On Rice glumes, associated with *Helminthosporium oryzae.*
,, G.—On mouldy patches on leaf-sheath of Maize, associated with *Helminthosporium* aff. *sativum.*
,, H.—*Helminthosporium curvulum* Sacc. from Baker's Fungi Malayana, No. 217.

PLATE VII.



Figs. A and D.—*Helminthosporium oryzae* B. de H., on Rice leaves, Ejura.
Fig. B.—*Helminthosporium* ,, ,, ,, Juaso.
,, C.—*Helminthosporium* ,, on Rice glumes, Adebrem.
,, E.—*Helminthosporium* sp. on leaves of *Pennisetum typhoideum*.
,, F.—*Helminthosporium ravenelii* Curt. on inflorescences of *Sporobolus pyramidalis*.
,, G.—*Helminthosporium ravenelii* Curt. tap-water agar culture of F.

PLATE VIII.

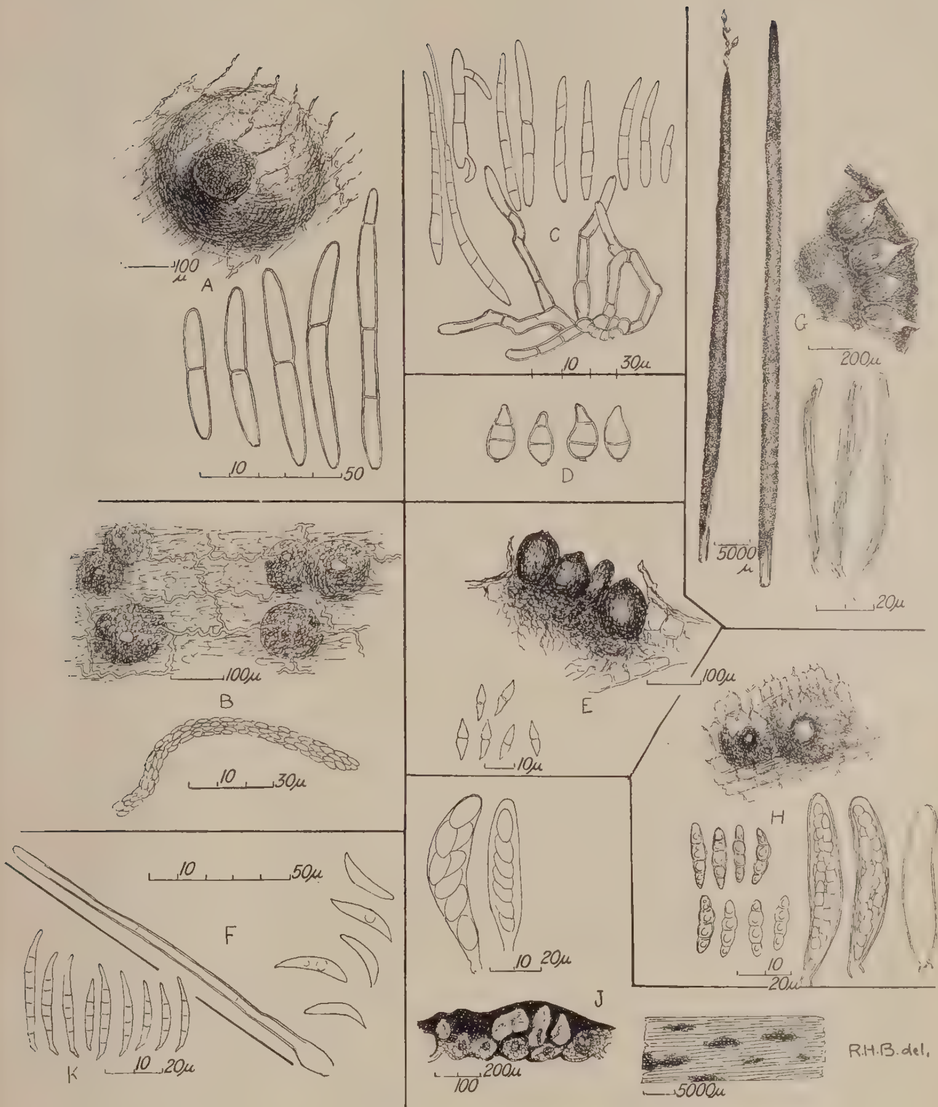


Fig. A. *Diplodia Macrospora* Earle, on Maize leaves and husks.
,, B. *Phoma zeicola* E. & E., on Maize leaves.
,, C. *Cercospora sorghi* E. & E., on Sorghum leaves.
,, D. *Piricularia oryzae* Br. & Cav. on Rice.
,, E. *Darluca filum* on *Imperata arundinacea.*
,, F. *Colletotrichum andropogonis* Zimm., on Sorghum leaves.
,, G. *Epichloe cinerea* B. & Br., on inflorescences of *Sporobolus pyramidalis.*
,, H. *Leptosphaeria sacchari* B. de H., on Sugar-cane leaves.
,, J. *Phyllachora heterospora* P. Henn., on leaves of *Panicum maximum.*
,, K. *Fusarium heterosporum* Nees. *forma one* Wollenw. on inflorescences of *Panicum maximum.*

PLATE IX.

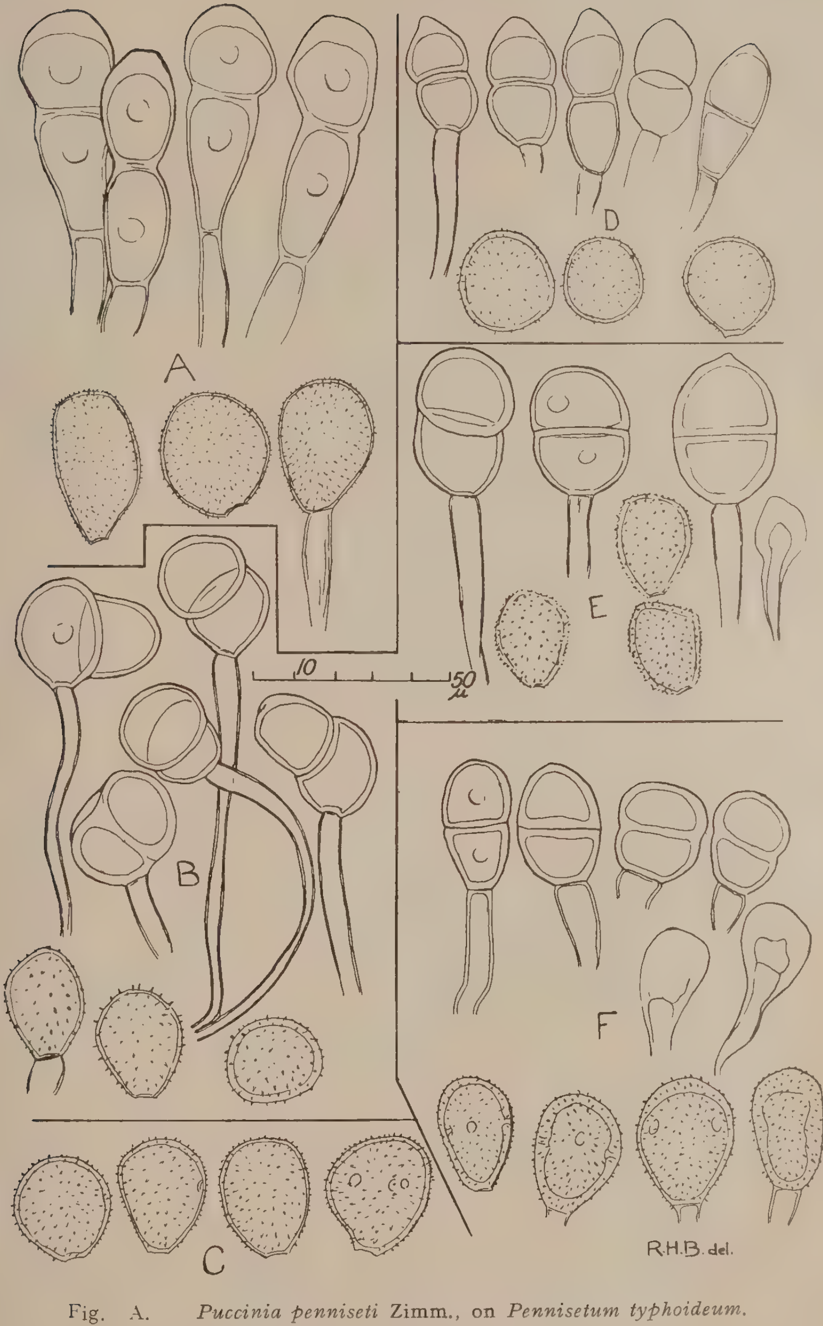


Fig. A. *Puccinia penniseti* Zimm., on *Pennisetum typhoideum.*
,, B. *Puccinia* sp., on *Rottboelia exaltata.*
,, C. *Puccinia* sp , on *Urochloa insculpta.*
,, D. *Puccinia maydis* Bér. on Maize.
,, E. *Puccinia* sp., on *Andropogon gabonense.*
,, F. *Puccinia rufipes,* on *Imperata arundinacea*

PLATE X.

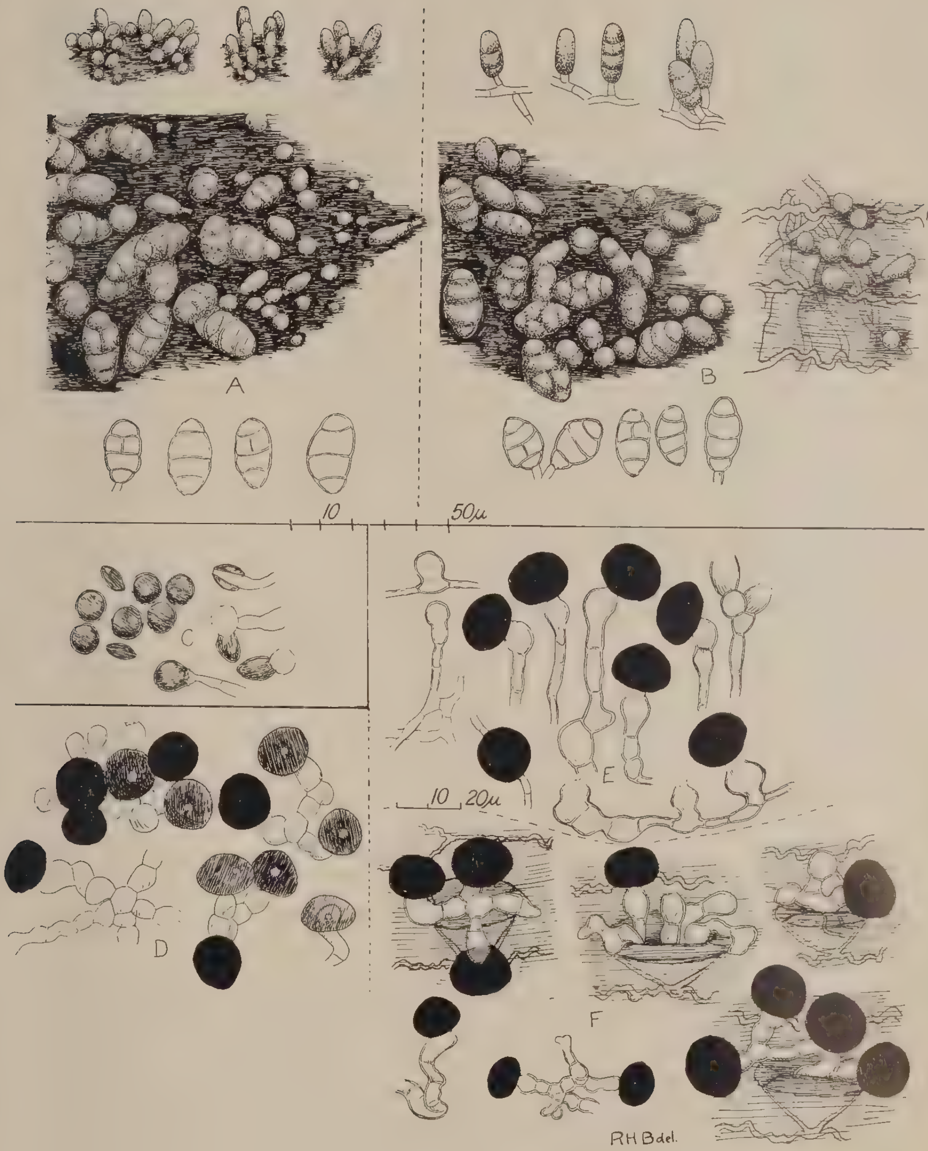


Fig. A. *Clasterosporium maydicum* Sacc., from Baker's Fungi Malayana, No. 217.
,, B. *Clasterosporium maydicum* Sacc., on Maize leaf, Aburi.
,, C. *Papularia sphaerosperma* (Pers.) v. Höhn, on Maize leaf.
,, D. *Nigrospora oryzae* (B. & Br.) Petch, on Rice leaves.
,, E. *Nigrospora sphaerica* (Sacc.) Mason, cassava-mush agar culture of F.
,, F. ,, ,, on Maize leaves.

PLATE XI.

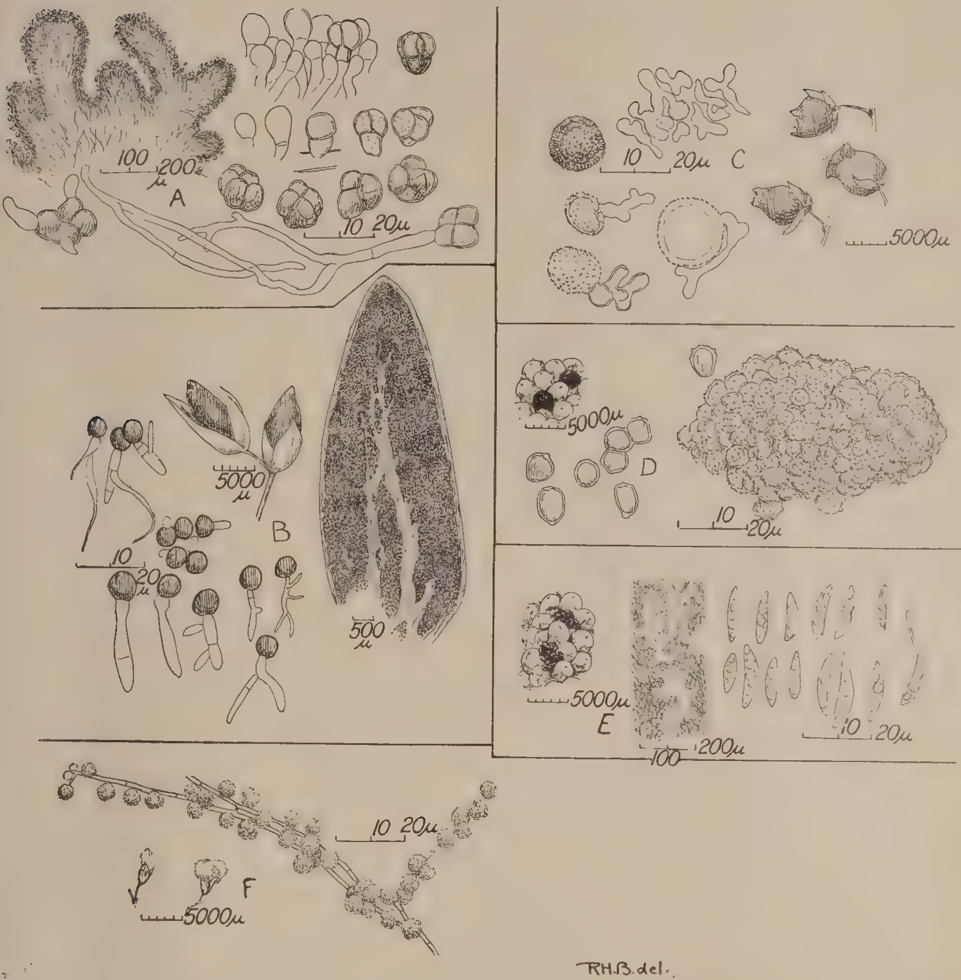


Fig A. *Cerebella cenchroidis* Subram., on *Pennisetum Polstachyum*.
,, B. *Sphacelotheca sorghi* Clint. on Sorghum.
,, C. *Ustilago heterospora* Henn. on *Panicum maximum*.
,, D. *Tolyposporium penicillariae* Bref., on *Pennisetum typhoideum*.
,, E. *Sphacelia sp.*, on *Pennisetum typhoideum*.
,, F. *Ustilaginoidea* on *Setaria sulcata*.

BULLETIN No. 11.

ABAṄ SE̱ṄKĒKÃ ṄHOMA A E̱TOSO DUBIAKÕ.

(For Local distribution only.)
(Ma oman yi nko ara.)

Department of Agriculture, Gold Coast.

Kua Adw̌umabea Wo̱ Sika Mpoano.

COCOA DISEASES PRESCRIBED BY THE PLANTS (INJURIOUS PESTS) ORDINANCE.

KOKŌ NYAREWA SE̱NEA MMOABÕNE A E̱SE̱E NUA HÕ MARA KYERE̱.

BY

R. H. BUNTING, F.L.S.,

Assistant Director of Agriculture for Research and Mycologist.

A Abaṅ Aḵuafohene Abadiaḵyiri a O̱pe̱ Afifide Nyarewa Hõ̱
Nse̱m Mũ Aḵwaṅ Kyere̱we.

Accra, } *April, 1927.*
Nḵran, }

FOREWORD.

NNIANIM.

It is hoped that this Bulletin will be found of great value to farmers and others interested in the welfare of the Cocoa industry in the Gold Coast.

2. The colour illustrations have been prepared by Mr. Bunting, Assistant Director of Agriculture for Research, and are technically accurate and of high intrinsic value. The blocks and prints were made by Messrs. John Swain and Sons, Ltd., of London, E.C.

3. For the Twi translation the Department of Agriculture is indebted to Mr. C. E. Clerk of Christiansborg. The Twi manuscript was revised by Mr. J. S. Martinson, Assistant Superintendent of Agriculture.

G. G. AUCHINLECK,
Ag. Director of Agriculture.

May 10*th*, 1927.

Yẹń anidaso sẹ sā Abań Sẹ́ńkẽkã ńhoma yi hõ bẹba mfaso kẹse amã Akuafo nè wọń a wọpẹ kokõ adw̌ūma yiyedi wọ Sika Mpoano no.

2. Owura Bunting Aban Akuafohene Abadiakyiri a ọpẹ afifide nyarewa hõ nsẹm mũ akwan no na osiesiee mfonini a wọakã no aduru no, na nsa anodwũma no hõ nni asẹm na ẹfata. Tintimnnua né ne tintīm nso yẹ Awuranom John Swain né ne Mma a wofi London na ẹyẹe.

3. Nea ẹfa Twī ńkyerase yi hõ nso Aban Akuadwumabea no da Owura C. E. Clerk a ofi Osu no ase pī. Twī nsa kyerẹw no nso Owura J. S. Martinson Aban Akuadw̌ūmafw̌ẹfo boafo no na ọhyehyẹe.

G. G. Auchinleck
ABAN AKUAFOHENE NSIANA'NM'.

May 10, 1927.

CONTENTS.

COCOA DISEASES MEAN LOSS OF MONEY.

KOK̄O NYAREWA KYERE̱ SIKA YERA.

---

1. Every year a very large amount of money which should belong to the farmer of this country is lost because a big proportion of his crop is destroyed by disease. No thief, or gang of thieves, could so effectively take from the farmer his wealth as do the numerous cocoa diseases that are well organised for that purpose and which appear to be increasing in quantity every season.

> 1. Dā afrihyia sika ke̱se a ankā e̱ha akuafo benyā no mu fā ke̱se pa ara se̱e wo̱ nyarewa nti. Ow̃ifo anā aw̃ifo kuw bi ara nntumi mmegye okuafo nsam ahõnyãde se̱nea kokō nyarewa dodow no ayi anim ye̱ no, na e̱ye̱ se̱ e̱ko̱ so dā mmoroso wo̱ kokō be̱bre biara mu.

2. If this is so it is only right that the Government should be anxious about the cocoa industry.

> 2. Se̱ e̱te sãa e̱n'de eye se̱ Abaṅ ani kũ adw̃uma yi hõ.

3. It may be asked what does it matter if cocoa diseases do increase seeing that we know that the quantity of cocoa for sale has every year been greater than that of the year before ?

> 3. Wo bebisa se̱, se̱ kokō dodow a wo̱to̱n afe biara mu no ko̱ so dā seẽṅ afe a etw̃aam' no a, e̱n'de e̱hõ nyarewa fa hõ de̱ṅ ?

4. The answer to that question is—If cocoa diseases are increasing on any tree the amount of cocoa produced by that tree must be decreasing, which means that every year the amount of money received for cocoa-beans must become smaller and still smaller than it should be.

> 4. Sā ase̱mmisa yi hõ mmuae ne se̱, se̱ kokō hõ nyarewa yi ko̱so dua biara so a, kokō dodow a e̱se̱ se̱ sā dua no sow no so behũaṅ, na e̱kyere̱ se̱ dā afe sika dodow a wonyā wo̱ kokō aba no hõ no e̱so behũan korā a e̱renko̱ anim.

5. Many farmers now complain that their trees are not yielding so much cocoa as they once did. Europeans who revisit the country after a number of years speak of the increased amount of disease they find now.

> 5. Akuafo pī di ṅko̱mo̱ se̱ kokō nnua no nnsow pī se̱nea kaṅ no e̱sow no.
>
> Abro̱fo a wo̱abe̱trā asase yi so pe̱ṅ no, se̱ mfe bi akyi wo̱san be̱sra ha bio a, wo̱kā se̱ nyarewa a wo hũ no ado̱so afei.

6. Apart from the devastating effect on cocoa cultivation which must follow the deforestation that has been going on for years

an increasing amount of disease must be expected in a country such as this where a foreign plant like cocoa is grown in such large numbers with so little done to maintain it in good health.

6. Osee a enam kwaebu (bebrebe) sode ba kokō adw̃uma yem' dā afrihyia no ṅkõ ṅkã mfũaw, etw̃a na etw̃a se nyarewa pī ba wo aduaba a emfi ha, na woadua wo sa asase yi so, na wommo hõ modeṅ mma ennyin yiye no hõ nti.

7. Cocoa is not a native of this country, its existence here cannot be continuously maintained unless efficient attention is given to it, any more than a European can live in West Africa, or a West African in England, unless he takes special precautions against local conditions which bring him disease. Nor is a cocoa-tree like any of the crops which farmers have been accustomed to grow from time immemorial. It is a permanent crop, unlike cassava, yams or any other plant which yield their produce within a few months of planting; it occupies the same piece of ground for many years. It cannot move from the place where it was planted when the air, moisture or food in that soil is exhausted, it must starve for want of one or other of these essentials, and a starved plant means a diseased plant, diseased plants mean reduced yields, and reduced yields mean less money.

7. Kokō mmfi asase yi so, senea ebeye na ebekye ha no gye se woma ani kũ hõ papāpa; yede beto Oburoni a waba Atoe Afrika ana Obibini a wako Eṅiresi Abrokyiri hõ, ese se ofw̃e né hõ so yiye wo eho mframa hõ, efise wannye sa a obeyare. Kokō dua nnté se nnua a aka a efi tetēte Akuafo ta dua dā afrihyia no bi. Eye dua a enyin kye, ente se baṅkye ana ode a wodua a asram kakra bi akyiaemu ade ba no, eno de esi babi a edi mfe pī, se fakõ a woduae ho mframa, foṅw̃ini anā emu srade sã na dua no annya sã nneema titiriw yi bi a, eto apẽ na eye grow a ekyere se dua no yare; dua yarefo yi kyere nnobae so hũan na nnobae so hũan de sika ketewa ba.

8. There would be very little to fear from cocoa diseases if farmers would realise: (1) that a cultivated, foreign, permanent crop like cocoa is not like a wild, native, forest tree which can look after its own interest, nor like an annual crop which has only a short life, and (2) that it must have suitable cultivation and conditions to maintain it in good health and yielding capacity.

8. Se akuafo no behũ nea edidi so yi a, en'de osuro kakra beba kokō nyarewa no hõ, ene se:—1) Dua a woahye nsa atew, na esi ho da se kokō no de ennte se eha kwaem' dua a eno ara nyin kwa, nanso ennte se nnobae a wonya dā afe na enkye na asa. 2) Ese se enya ofwe pa na anya ahooden asow pi.

9. It is because the farmer does not take sufficient care of his cocoa trees that the Government introduced the Plants (Injurious Pests) Ordinance, and put into practice in 1925 the scheme whereby cocoa-farms might be cleared of disease. In each Province of the Colony and Ashanti, European Officers who know how to treat diseased trees took gangs of labourers into farms, invited the cocoa farmers to assist them, in some cases going so far as to pay the owners for the work they did on their own farms, and they treated all the diseases they found on those farms. But it was found that the farms had been so neglected that it would take too long to deal with the whole of the cocoa area within a reasonable period of time, and that, whilst some districts would thus be benefited, the big majority of farms would have to be left to the ravages of disease for many years to come.

9. Esiane sẹ okuafo no ṅṅfw̃ẹ ne kokō nnua so yiye nti na Abaṅ ahyẹ kokō yare a ẹsẹe afifide hõ mra wo afe 1925 mu de Kyẹrẹ sẹnea ẹbẹyẹ na oyare befi kokō mfuw no mu. Asase yi so Amansin horow yi mu bi ara nè Asante ṅhina Abrọfo Adw̃umayẹfo a wonim sẹnea wosi sa nnua ayarefo yi yare no faā apāfo kuw kọọ mfuw no mu, wọfrẹfrẹe kokō akuafo no sẹ wọmoa wọṅ, mpo ẹtọ dabi a wotua akuafo a wọyẹ wọṅ ankasa afum adw̃uma no ka wọ ọboa a wọboa wọṅ no hõ nti, na wosaa nyarewa a wohui wọ mfuw no so no nhina. Na wohui sẹ wọṅṅfwe mfuw no kyea korā, nanso ẹbẹkyẹ ansa na woatumi ayẹ kokō dodow a wobehũ wọ fākō ana mmeae horow a wodua họ nhina hõ adw̃uma wọ bre a ẹsẹ mu, na bre a omaṅ no bi beṅyā eyi yẹ mu mfaso no na emu fā kẹse ara de wobegyaw ato hõ na ọyare no asẹe no wọ mfe bi a ẹbẹba no mu.

10. The only way to overcome such unfair treatment is for the Inspectors of Plants to visit each district and, as there is not sufficient time to treat each farm in that district, to call all neighbouring cocoa growers to a central farm, and there to show them how to deal with their trees to bring them into a condition of good health, so that they may produce as much cocoa as is possible.

10. Ọkwaṅ a wọbẹfa so ama wọṅ ṅhina anyā ofw̃e yim' mfaso ne sẹ Afifide so Afwẹfo no bẹsrasra Amansin biara mu na esĩan'e sẹ worennyā hõ kwaṅ ṅkọ afuw biara mu no wọ mansin biako mu nsa ayare no nti, nea wọyẹ ne sẹ wohyia akuafo a wọṅ mfuw bemmẹṅ họ no ṅhĩnā ba afuw biako mu na ọkyẹrẹ wọṅ sẹnea wọnyẹ wọṅ kokō nnua no mfa na anya ahõọdeṅ asow yiye sẹnea ẹsẹ.

11. The work will necessarily cost a great deal of money, but the Government feels that the importance of the cocoa industry to the inhabitants of this country is so great that the expenditure is justified in an attempt to save the trees which produce so much wealth.

11. Sa adw̃uma yi begye sika pī, na Abaṅ nim sẹ mfaso kẹse a asase yi so fo nya fi kokō adw̃umayem' nti sẹ wọfw̃ere sika de gye nnua a ẹde ahõnyāde pī ba no nkwa a ẹfata.

12. But this work will be useless; the money will be spent in vain, and the important industry will be placed in jeopardy if the farmers, after having been shown how to treat their wealth-producing trees, neglect to put such demonstration into practice. And it will be necessary for the sake of the industry that the Government punish the negligent farmer.

> 12. Nanso sẹ wọkyerẹ akuafo no kwaṅ a womfa so fw̃ẹ nnua a ẹde ahõnyãde ba yi, na woamfa akyerẹkyerẹ yi annyẹ wọṅ asõ so asẹm anni so a, dw̃uma yi ne emu sika sẹe yi bẹyẹ humũ na ama kokõ adw̃uma a ẹhõ hĩa yi asẹe. Kokõ adw̃uma yi nti etw̃a na etw̃a sẹ Abaṅ tw̃ẽ Okuafo a ọnfwẹ n'afuw so no asõ.

13. In all civilised countries there are laws in force to compel farmers to treat by a given method crops which are attacked by disease. Punishment for neglecting to do so is sufficiently severe to ensure the work being done.

> 13. Anibue aman ṅhinã mu wọahyehyẹ mra a wọnam so hyẹ Akuafo no kyerẹ wọṅ kwaṅ a wọfa so bọ afifide hõ nyarewa ano. Asõtw̃ẽ a ebata hõ a wonam so tw̃e wọṅ a wọanni mara no so asõ no mu yẹ dẽṅ ara gyeṅṅ, sẹnea ẹbẹyẹ na wọbẹyẹ adw̃uma no yiyẹ.

14. Such laws are necessary, because, although a farmer may do what he likes with his own crops, he may not let them spoil his neighbours' crops by giving them disease.

> 14. Sa mra no hõ hĩa efisẹ okuafo tumi yẹ sẹnea ọpẹ wo nafifide hõ nanso ẹnsẹ sẹ ọmã nafifide hõ nyarewa no saṅ ne yọnkõ de.

15. Plant diseases spread from tree to tree, from pod to pod, with as much ease as human diseases do from one person to another, and one cocoa farm that bears disease is consequently a very grave danger to the farms around it. There can be no question that, in this country, as in all other countries, the negligent owner who allows his farm to develop disease, after being told what he must do to combat that disease, should be punished severely for the danger he is causing to his neighbours, and to the valuable industry upon which the wealth of the country is based.

> 15. Senea oyare di nsaṅ wọ nnipa hõ no saara nso na etumi ba nnua nè aba hõ, na kokõ afuw a ọyare aba mu no, ẹde amane kẹse aba mfuw a atw̃a hõ ahyia no sọ. Ẹda ho faṅṅ sẹ sẹnea wọyẹ no nsase foforo so no saara na wọbẹyẹ wọ ha, ẹne sẹ afuw wura biara a ọnfw̃ẹ n'afuw so yiye na ọma nyarewa ba mu bre a wọakyerẹ no kwaṅ a ọbẹfa so abo nyarewa yi ano no wọtw̃e n'aso yiye efisẹ ode amane kẹse aba ne mfẹfo ne adw̃uma a ẹsom bo a asase yi ahõṅyade gyina so no so.

16. For many years the Department of Agriculture has been trying to convince cocoa-farmers of the necessity of looking after their farms and of the grave danger of allowing diseases to be untreated.

> 16. Mfrihyia pī ni Kuadw̃umaye̱bea no mu fo abo̱ mo̱deṅ se̱ wo̱ kyere̱ kokō akuafo no hīa a ehīa se̱ wo̱fw̃e̱ wo̱ṅ mfuw no so yiye, na wokyere̱ wo̱ṅ amane ke̱se a se̱ woansa kokō hõ nyarewa yi a e̱be̱fim' aba nso.

17. Some Amanhin and a few farmers have been able to grasp the truth of the advice given, but in many cases farmers, who were told all about how to treat their trees and the real necessity of so doing, have pleaded ignorance when on a later visit it was found that they had done nothing.

> 17. Amanhene nè Akuafo no mu kakra bi aso afotu yim' dennen na e̱ta ba se̱ se̱ wo̱kyere̱ Akuafo no se̱nea wo̱nye̱ wo̱ṅ kokō nnua no mfa ne nea enti a e̱se̱ se̱ wo̱ye̱ sā no a wo̱kã se̱ wonnim, na e̱ye̱ kakra na wo̱ko̱sra wo̱ṅ mfuw no a wohu se̱ wonnye̱e ho fw̃e e̱.

18. To make sure that such ignorance does not continue, the Department of Agriculture has prepared this book for wide-spread distribution to show what the prescribed cocoa diseases look like, and telling the reader how to treat them.

> 18. Se̱nea e̱bi̱ye̱ na onim a wonnim yi reṅko̱so da nti Kuadw̃u-maye̱bea fo asiesie sa ṅhoma ketewa yi ama asõ wo̱ṅ ṅhina so ama wo̱ahũ se̱nea o̱yare no nkyerekyerem' te na wo̱fa so kyere̱ o̱kenkanfo no o̱kwan a wo̱mfa so nsa oyare no.

19. The diseases with which the Ordinance is concerned are as follows :—

Injurious Pests.	*Prescribed Treatment.*
A.—Black Pod Mealy Pod Pod Rot	All pods which are not utilised for crop shall be removed from the trees.
B.—Stem Canker	Excision of diseased material and the immediate destruction thereof by fire and the treatment of the wound with hot tar.
C.—Collar Crack White Root Disease Brown Root Disease Collar Rot	Digging out the entire plant, its immediate destruction by fire and the isolation of the affected area by a trench not less than two feet deep.

D.—White Thread Horse-Hair Blight Loranthus Parasitic on Cocoa Orchids found on Cocoa	Removal and immediate destruction by fire of the pests and the damaged portions of the plant.
A.—1. Abayare tuntum 2. Abayare fitā 3. Aba a aprow	A.—Aba a e̱hõ nni mfaso wo̱m-mfa mfra nno̱bae mu no e̱se̱se̱ wo̱tew fi dua no hõ.
B.—Dutaṅ hõ ntrutrui ...	B.—Tw̆a o̱yare no fi ho̱ fa ogya hyew na fa amã (Kōta) hyew-hyew kã so.
C.—Dua ase mpāpae Ntini yare fitā Dua ase prow Ntini yare dodowe	C.—Tu dutaṅ no nhina hyew nte̱m so, na tw̆a o̱kã kōntōn-kroṅ anamon abien hyia fãko̱ ho̱.
D.—Asawa ana hama fitā Hama tuntum yare Nyankonuru (Krãmpã) Ahum-ne-aham	D.—Tw̆anea o̱yare no̱ ase̱e ho̱ no kyene nafa ogya hyew nyarewabone yi nhina.

"Wogugoru woba kuru hò a etw̆a ne naṅ."

PLATE 1.

BLACK-POD DISEASE

POD DISEASES.

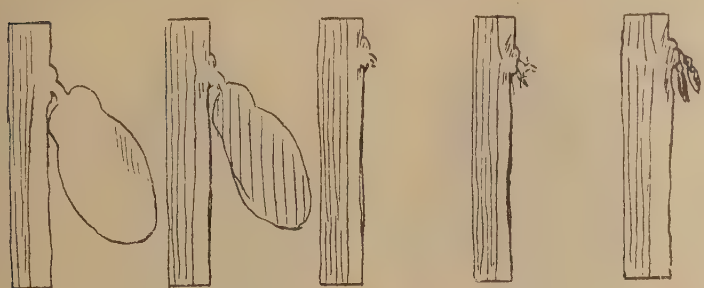
ABA NYAREWA.

20. There are three pod diseases which the Ordinance prohibits because they are responsible for spoiling a large amount of cocoa every season which should be converted into money. Each of these diseases has peculiarities of its own, but as the treatment for them all is the same we will consider them together.

20. Aba nyarewa yi nam ahrow 3 a mra no siw kwan, efise̱ sa nyarewa yi na e̱se̱e kokō ke̱se a e̱sese̱ wonya da kokōye̱ bre mu a e̱de sika ba no. E̱sõnõ sa nyarewa yi biara su na esĩane se̱ o̱kwan a wo̱fa so sa ne nhina yare no ye̱ biako nti ye̱be̱bobo̱ ne nhina mũ asusuw.

21. They each begin to show their presence by changing some small portion of the pod to a brown colour, as is shown in the pictures of Black Pod disease and of Mealy Pod disease (Plates 1 & 2). It is at this early stage that they should be removed from the tree because the mould which causes them very quickly produces disease-seeds which are capable of giving the disease to healthy pods, moreover in the case of the Black Pod disease the fungus is liable to get into the bark of the tree from the pod, and so spoil next season's crop.

21. Emu biara kyere̱ se̱nea e̱ye̱e na e̱bae, e̱ne se̱ aba no fã babi dow ko̱ se̱nea wohũ wo̱ aba tuntum no nè aba yare fita no mfonini mu a e̱kyere̱ se̱nea nyarewa no te no (Mfonini 1 and 2) Sã mfiase bre yim pe̱ na e̱se̱ se̱ wo̱tew aba no fi nnua no so efise̱ o̱yare no na e̱ye̱e kokō no sa na e̱sow o̱yare aba nte̱m na e̱mã o̱yare no san aba pa no. E̱de refa aba tuntum yare hõ no etumi fa aba no mu hyeṅ dubonã no mu a e̱nam so se̱e afedan aba a e̱be̱sow no nhina.



A B C D E

22. If we cut through a pod that has just been attacked by the Black Pod disease we shall find only a small portion spoilt as is shown in the above drawing marked A. If we leave the pod on the tree, the disease will soon spoil the whole of the pod and get into the bark as in B. There it will remain after the useless pod has fallen as in C, and although we may get flowers forming next

season as in D, the crop which follows will be like that shown in the drawing marked E. Not only so but the disease may spread within the bark and form a canker (see plate 5) which will probably spoil the crop for many years to come.

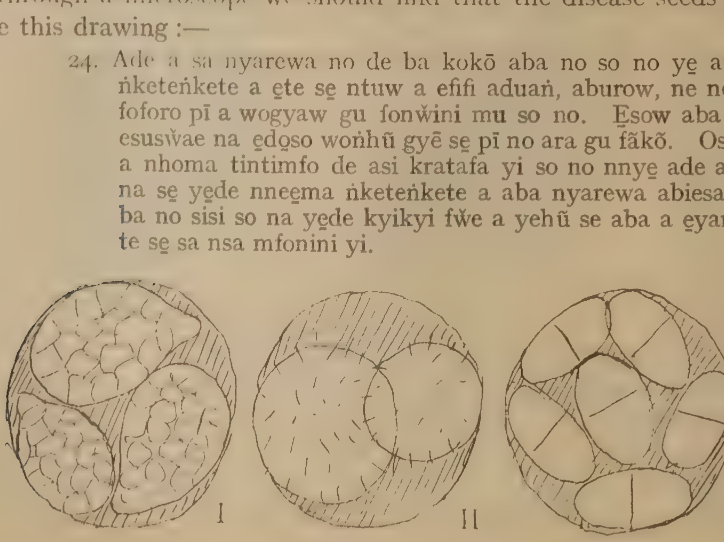
22. Se̱ ye̱pae aba a o̱yare tuntum yi bi aka no no mu a, yebehũ se̱ emu fã ketewã bi na ase̱e se̱nea e̱te wo̱ nsa mfonini "A" a edi soro no mu no. Se̱ yegyaw aba no wo̱ dua no so a o̱yare no be̱se̱e aba mu no ǹhina nte̱m na asaǹ dubonã no se̱nea e̱te wo̱ nsa mfonini "B" mu no. E̱wo̱ ho̱ saara bre a aba a ase̱e no atew ato fam no se̱nea "C" kyere̱ no, e̱wom se̱ ebegu ǹfŵireǹ ama afedan kokõ no de se̱nea "D" kyere̱ no, nanso aba a efi mu ba no te se̱ nea wakyere̱ wo nsa mfonini "E" mu no. E̱nnye̱ sã nkõ na mmom oyare no be̱fŵete ako dubonã no mu ama aturuturuw (fwe mfonini pon 5) na ase̱e aba no mfe pĩ akyi.

23. The brown discoloration of the pod rapidly increases in size until the whole of the pod is changed from its healthy colour to brown and later to a black, dried up, useless pod whose existence indicates that the farm owner is a foolish or ignorant person.

23. Aba no dodowe no ko̱so yere̱w kosi se̱ aba a e̱te apow no mu no ǹhina be̱sakra adow ko̱ na akyiri no adaǹ tuntum na atwintwam a e̱hõ nni mfaso na e̱ba sa a e̱kyere̱ se̱ afuw wura no ye̱ o̱kwasea anã obi a onni adŵene.

24. The mildews which give these diseases to cocoa pods are very small plants similar to those that grow on food, corn cobs, and many other materials that are left lying about in the shade. They produce a very large quantity of seeds that are so small they cannot be seen unless a number of them are together. The full stop which the printer has used on this page is not a big object, but if we cover it with spores of the three pod diseases and look at it through a microscope we should find that the disease seeds look like this drawing :—

24. Ade a sa nyarewa no de ba kokõ aba no so no ye̱ afifide ǹketeǹkete a e̱te se̱ ntuw a efifi aduaǹ, aburow, ne ne̱e̱ma foforo pĩ a wogyaw gu fonŵini mu so no. E̱sow aba pĩ a esusŵae na e̱do̱so woǹhũ gyẽ se̱ pĩ no ara gu fãkõ. Osiŵiei a nhoma tintimfo de asi kratafa yi so no nnye̱ ade a e̱sõ, na se̱ ye̱de nne̱e̱ma ǹketeǹkete a aba nyarewa abiesa fim' ba no sisi so na ye̱de kyikyi fŵe a yehũ se aba a e̱yare no te se̱ sa nsa mfonini yi.



I II III

MEALY-POD DISEASE

POD ROT

25. There would be at least :—

I.—On the Black Pod disease "full stop" three fungous fruits containing from 15 to 30 disease-seeds each ;

II.—On the Mealy Pod disease "full stop" two disease-seeds; and

III.—On the Pod Rot "full stop" six disease-seeds.

25. Nea ẹbẹyẹ ara ne sẹ :—

I.—Aba tuntum siw̌iei so no ntuw no aba abiesa biara kura oyare aba fi 15 kosi 30.

II.—Aba yare fitã siw̌iei so no oyare aba 2 na ẹwọ so.

III.—Aba a ẹprow siw̌iei no ọyare aba 6 na ẹwọ so.

26. Think how many full stops it would take to cover a cocoa-pod, and how many disease-seeds are required to cover each full stop on that pod, and then remember that the disease-seeds are piled up on the pod, not lying flat as they are shown above, and you will get some idea of the enormous number produced by any one pod that is diseased.

26. Dweṅ osiw̌iei dodow a ẹbẹkata kokō aba hõ ne aba a ẹyare yare-dodowe a ẹbẹkata osiw̌iei biara hõ na afei kae sẹ aba ṅketeṅkete a ẹyare yare yi aboa wọṅ hõ ano kuw wọ kokō aba mũa bakõ so ẹmmfemfãm so sẹnea wohũ wo mfonini a ẹwọ soro no mu na ẹbẹkyerẹ wo dodow kõ a ẹwọ kokō aba a ẹyare hõ.

27. Go into your farm in the early morning and you will find that pods suffering from black pod disease are coated by mildew, that those attacked by the Mealy Pod disease are covered with masses of white or pink meal, each grain of which is a disease-seed, and that all the cases of Pod Rot are surrounded by a thick layer of black dust which consists entirely of disease-seeds. Now consider that, when those disease-seeds are blown away by the breeze, washed off by rain, carried away by insects or animals, the mildew within the diseased pod will produce just as many again, and you will agree that pod diseases at any rate are well organised to steal produce from the farmer.

27. Kọ wafũm anọpahema na wo behũ sẹ kokō aba tuntum a ọyare yi ayẹ no sẹnea agye ntuw, na nea abayare fitã ayẹ no nso bribi a ẹte sẹ aduan fitã a ẹdaṅ yẹ kokō sẹ pī ahura hõ, na aba a aprow no bribi pipri a ẹte sẹ mfutuma ahura hõ a ne ṅhina kura ọyare aba, na ẹba sã a en'de aba a ẹwo kokō no mu nhina yare anã asẹe. Afei fa hõ adwene sẹ sẹ mframa bọ aba a ayare ana asẹe, sẹ nso osu tọ na egu fam a mmoamoa tw̌e kọ na ntuw a ahura kokō aba a ẹyare yi hõ no bẹma foforo aba bio, na wobẹte ase sẹ kokō aba a ẹyare anase asẹe yi ọkwaṅ biara so no asiesie ne hõ sẹ ẹbegye okuafo nsam ne nnobae ṅhina.

28. Each disease-seed produced on a pod is capable of causing disease to healthy pods. If you wish to test whether this statement is true, make a small wound in a healthy, nearly ripe pod and place on the wound the smallest possible quantity of the growth you find on a mealy pod, and see what happens in a day or two.

28. Aba a ẹyare biara a ẹwọ kokō aba mu tumi ma nea ẹte apow no nhina yare. Sẹ wo pẹ sẹ wo hũ sẹnea mekã yi yẹ nokware a, fuaw aba hõọdenfo a agyigye biako hõ kakra, na fa aba yare fita a ẹte sẹ aduaṅ no bi ka anim na dakro ana nnanu akyi wo behũ sẹnea ẹbẹba.

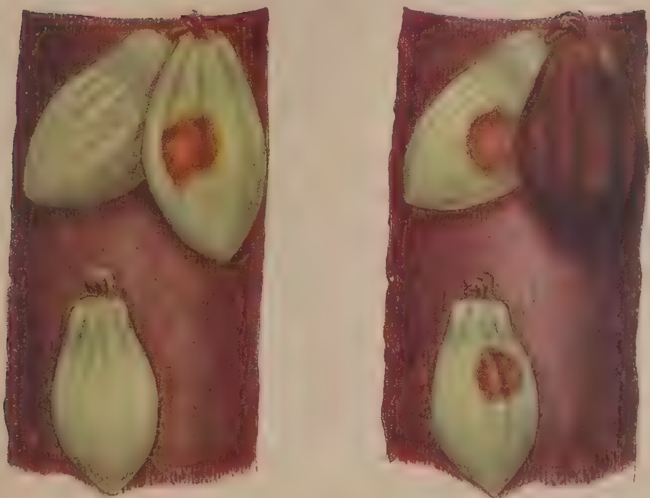
29. There was once a farmer who had three pods growing near one another on a cocoa tree, and one, like that one at the top of Plate 3 became diseased. It was not a large spot of disease, and the pod was not quite ripe, so the farmer did not take the trouble to cut it off. But that spot grew until in a day or two the whole pod was discoloured and the disease had travelled to the healthy pod that was touching it ; moreover the pod growing underneath was soon attacked by disease-seeds carried from the ones above it. So that a little later, when the farmer went to see whether the pods were ready to cut, he found three black pods that were useless to anyone. If he had been a wise man instead of a tired and ignorant fellow he would have cut off that first pod when he saw the first sign of disease, and the chances are on his next visit he would have found two healthy pods together like those at the bottom of the picture.

29. Bere bim' okuafo bi wo kokō dua a aba abiesa tuatua so a ne nhina bobo hō na emu biako te sẹ nea ẹwọ mfonini pon 3 no sro no a asẹe ana ayare. Fākõ a ọyare no wọ no nsõ pī bi na esiane sẹ kokō no nwiei bre nti okuafo no anhaw ne ho antwa ankyenẽ. Enna sā fã no terẹwe na dakro anā nnānu akyi no kokō aba no ṅhina su sakrae, na esiane sẹ nea ẹte apow no beṅ nea ẹyare no nti ẹsann no bio, nso aba a ẹsensẹn ase no nea etuatua soro no yare-aba no saṅṅ nea ẹwọ ase no. Mmere tia bi akyi no okuafo no kofwẹe sẹ aba no abre ana na watew na ohũũ aba tuntum 3 a ne nhina hõ nni mfaso. Sẹ ọyẹ onyansãfo na ọnnyẹ okwasea a wabrẹ a, aṅkã bere a ohũi sẹ aba a edi kan no sẹe rededa akwaṅ no otẇaa sā aba no kyenee na nea ẹbẹba ne sẹ ne nsra fẇẹ a ẹdi kaṅ no mu no obehũ aba abien a ẹte apow te sẹ nea ẹwọ mfonini no ase họ no.

30. It is because the Government knows that (1) pod diseases are caused by moulds, (2) these moulds produce innumerable seed, and that (3) each of these seeds is capable of giving disease to healthy pods, that the treatment prescribed for pod diseases is to cut off from the tree all pods that are not used for harvesting and to bury them in the soil where their seeds can do no harm, or to kill disease by burning them.

30. Esiane sẹ Abaṅ nim sẹ :—(1) Aba nyarewa yi ntuw na ẹdeba nti (2) sa ntuw yim' biara tumi ma kokō aba a ẹte apow no yare nti ọkwaṅ a wọakyerẹ sẹ wọmfa so nè sa nyarewa yi nni ne sẹ wọbẹtetew kokō no ṅhina a wọmmfa mfra nea wọbeton na wọahyew ana woatu amõa de ne nhina ahyẹ fam wọ fākõ a aba no nntumi nsẹe bribiara họ.

POD DISEASES



Disease spreads from pod to pod by contact, or by its seeds being carried by the breeze, falling water, or by insects.

If a diseased pod is allowed to remain on the tree it will spoil other pods.

If it is removed early the other pods have a chance to ripen

31. But these diseases are cunning enemies, they do not necessarily depend upon the seeds they produce on the outside of the pod for their reproduction ; some of them produce inside the pod another kind of seed which has a tough, thick skin specially provided to keep that seed alive when conditions are unfavourable to its growth, or the mould may go on living long after it has killed the pod. So we must also arrange that the cocoa husks, after their contents have been removed, either be buried or burnt by fire because of the resistant disease-seeds they may contain or the seeds they may produce on their surface. Look at a heap of cocoa husks in the early morning after they have been broken and you will find mildew everywhere, and plenty of disease-seeds for the breeze, or for insects and birds, to carry to healthy pods.

31. Na sā nyarewa yi ye̱ atāmfo aniferefo, wommfa wo̱ń aba a wo̱pae wo̱ kokōhonõ no akyi so mfe̱e, ebinom pae aba fofro bi hye̱ koko̱ aba no mu a sā aba no ẘere ye̱ pèprē a wo̱ahye̱ da aye̱ se̱ wo̱de be̱koro aba yi so wo̱ bābi a e̱rennyã anyińye ho̱ anāase̱ ntuw no se̱ ekũru kokō aba no po a e̱tumi nyiń kye̱. Ne sā nti e̱se̱ se̱ ye̱fẘe̱ na se̱ ye̱bo̱ kokō no wie ara pe̱ a honõ no yetu amõa de hye̱m' anāse̱ yehye̱w wo̱ ababone a e̱hye̱m' ne nea e̱da adi no hõ no nti. Edu ano̱pa hẽmã a fẘe̱ kokō honõ a woaboa ano na wobehũ ntuw no̱ so bābiara se̱ nso nyarewa aba a mframa huw gu na mmoammoa anā nnomā soa ko̱ma aba a e̱te apo̱w no.

32. It is a danger to your own, and to your neighbours' farms to leave cocoa-husks lying about because of the disease-seed they may contain.

32. Se̱ wogyaw kokō hono no gu woafuw so a aba a ewo̱m no nti e̱nnye̱ wo ńkõ na wo hũ mu amane, na wo mfe̱fo mfuw a e̱be̱ń wode no nso hũ amane saara.

33. It is a danger to leave pods on the tree after they have become diseased because of the disease-seeds they will produce. It is a danger to leave diseased pods on the tree because of the disease getting into the bark.

33. Se̱ wo kōkō a akyẽń a e̱yareyare senseń dua so a e̱de amane ba, e̱ne se e̱be̱mã o̱yare no ahye̱ń dubonã no mu.

34. A wise farmer will bury husks and pods in the soil at least 9 inches deep so that disease-seed may be rendered harmless.

A wise Government should compel the negligent farmer to do the same so that his neighbour's crop may not be spoilt as well as his own.

34. Okuafo nimdefo bi ara betu amõa a emũ do̱ be̱ye̱ nsateakwā 9 de honõ no ńhinã ahye̱ mu, se̱nea e̱be̱ye̱ na na o̱yare no remfa amane mma bio. Abań anyansãfo be̱hye̱ okuafo dẘenharefo biara ama waye̱ sāara se̱nea e̱be̱ye̱ na e̱remma né yo̱ńkō nnobae nnse̱e.

STEM CANKER.
DUA HÕ NTRUTRUI.

35. In cocoa-farms where conditions are very damp we can sometimes find a disease of the stem called Stem Canker. This disease first shows itself as a purplish coloured juice being squeezed out of the bark of the tree. It is nearly always found close under, or near by, an old dead cushion which once bore pods. If the weather is dry and hot, the juice dries to a pink, rusty coloured patch, but after a shower of rain, when the rest of the stem is dry, that patch will remain moist for some time.

35. Kokō mfuw a ẹwọ nea ēhọ yẹ fọkyē no ẹtọ dabi a yehũ yare bi a wọfrẹ no dua hõ ntrutrui wo họ. Sā yare yi nea edi kań no ẹde nsukyī kọkọ sé yi ne subań adi fi dubonã no mu. Wotā hū sā yare yi wọ dua a asow na wọatew wọ họ peń no aniwa ase bābi. Sẹ ẘim wó anā ẹyẹ hyew a, nsu no kyēnkyēn fa su pọtọ kọ sé wọ fākõ họ na sẹ osu gu ẘie a bre a dua no hõ ńhinā awo no, fākõ họ yẹ fọkyē kyẹ.

36. The bark underneath this patch soon dies and cracks, and in bad cases pieces of the dead bark fall out and show the wood underneath to be discoloured by a purplish stain (as in the bottom picture of Plate 4). If conditions are favourable to the disease it spreads to a bigger area and causes a lot of damage.

36. Dubonã a ẹwọ beae yi ase no wu na ẹpaepae, na sẹ asẹe pī a nasińasiń no totọ na eyi dua a ẹhyẹ ase no adi fãńń sẹ ńkekãe kọkọ bi akekã mu sẹnea yehũ wọ mfonini pōń 4 a ẹwọ ase yi mu no. Sẹ ẹhọ gye oyare no de a emu terẹw anā emu yerẹw ne ẹma ade pī sẹe.

37. The bark of a cocoa tree is more important to that tree than skin is to a man's body, because not only does it serve to protect the structure inside but it also contains the veins which convey the tree's blood wherever it is wanted. So that if the bark of the stem is badly injured and does not heal quickly the roots cannot get sufficient of the blood of the tree which is manufactured in the leaves, to keep up their growth, and if they cannot grow they cannot drink in enough food from the soil to nourish the tree properly, and the result must necessarily be a smaller number of pods. Not only so but, as we saw in the case of the black-pod disease, we cannot expect to find pods on cushions killed by canker.

37. Kokō dubonã no ho hīa dua no seń sẹnea onipa ẘere hõ hīa mã no, efisẹ ennyẹ sẹ ẹbọ dua no hõ bań nkõ, na mmom ẹsań kura ntinī a ẹtẘe dua no mu nsu kọ babiara a ehīa sẹ nsu no kọ. Enti sẹ dua no hõ boń ba kãm pī na ańkoro amfa so ntẹm a ẹn'de dua no ntini ntumi ntẘētẘē nsu a efi ńhabań no mu no ma entumi nnyiń, na sẹ nnua no annyã anyinye a ẹn'de enntumi nnyã asase no mu srade sẹnea esẹ mmfa nyẹń dua no yiye na ẹbẹba sẹ ẹbẹsow aba ńketewa bi.

Ẹnnyẹ eyi ńkõ na sẹnea yehũ wọ abayare tuntum hõ no ẹremma sẹ aniwa dedaw a ntrutrui no akum no no bẹsow aba.

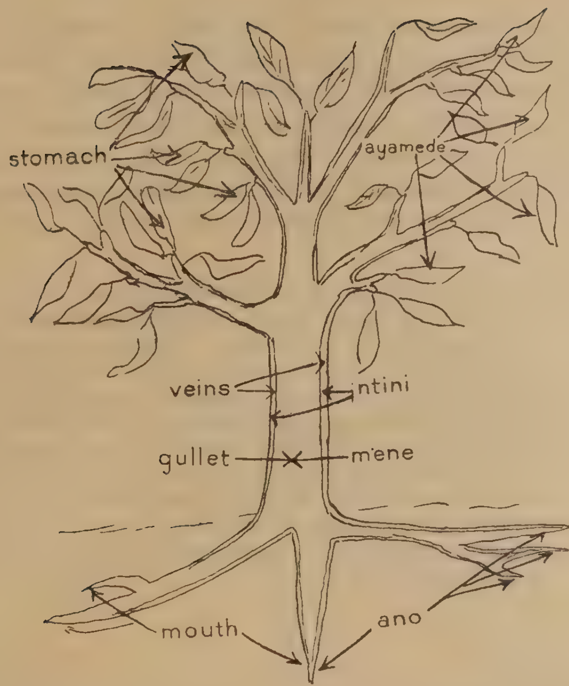
STEM CANKER

early stage

later stage

PLATE 5.

CANKER CAUSED BY BLACK POD DISEASE



38. The mould which causes stem canker is the same one which causes black-pod disease. The roots of the mould get into the stalk of the diseased pod and if the weather is wet the bark around the cushion is killed and the mould-roots go on growing until a large area of the bark is dead and useless. If the diseased pod were removed before the mould had travelled into the bark there would be no canker. Look at the cocoa pod on Plate 5; if we leave it on the tree it will soon become rotten and will probably give rise to a canker as is shown on the left-hand side, but if we cut it off as soon as it is found there is every hope of getting a crop next season, as is shown on the right-hand side of the picture.

38. Ntuw a ẹde dutan ntrutrui ba no ẹno ara ẹde aba yare-tuntum no ba. Ntuw no ntini hyẹṅ abã a kokō yarefo no tua so no mu na sẹ mframa no yẹ fọkyē a ekũm bõṅ a ẹkata aniwa no hõ no, kọso nyiṅ kosi sẹ bõṅ no fã kese paara wu a mfaso bi nni hõ. Sẹ woyii aba yarefo no họ ansã na ntuw no hyẹṅ bõṅ no mu a ntrutrui mma. Fw̃ẹ kokō aba a ẹwọ mfonini põṅ 5 so no, sẹ yegyaw wọ dua no so a ẹreṅkyẹ na ẹbẹprọw, na ampara dua ntrutrui yara ba sẹnea ẹte wọ mfonini no beṅkũm so no, na sẹ yehũ pẹ na yetw̃a a anidaso wọhọ sẹ yebenyã nnobae pĩ wo kokō bẹbre a edi so no mu, sẹnea ẹte wọ mfonini no nifã so no.

39. The Ordinance tells us that to treat cases of stem-canker we must cut out the diseased material and paint the wound so made with hot tar. That means that we must keep on cutting away the bark until the cuts reach healthy bark which will have a chance

to grow over and heal the wound. Hot tar is painted on to the wood to keep out insects and other moulds until the bark has grown over it. Canker is something like an abscess which cannot be cured until all the diseased matter has been removed. And because the diseased bark of canker contains the roots of the mildew and can produce disease seeds, the Ordinance says it should be burnt directly it is cut off so as not to allow the seed to cause disease on healthy pods or stem.

39. Mra no kyere̱ ye̱ṅ se̱ dua ntrutrui yaresa ne sé yetw̌a nea o̱yare no wo̱ hõ no kyenẽ na ye̱de amã hyewhyew kã ho̱. E̱no kyere̱ se̱ e̱se̱ se̱ ye̱ko̱so tw̌a bõń no kosi se̱ e̱be̱to bõṅ a e̱te apo̱w no na anyã o̱kwan akoro afa so na asa yare no. Wode amã (Kōtā) hyewhyew no ka dua hõ de apam mmoammoā nè o̱yare fofro a e̱kã hõ no kosi se̱ bõṅ no be̱kro afa so. E̱to̱ dabi a dua ntrutrui yare no te se̱ po̱mpo̱ mu nsu a wonntumi nnsa gyēse̱ wo̱ayi nsubone yi nhinā ho̱. Esĩane se̱ dua ntrutrui no bonã no kura o̱yare ntini a e̱pae yare no nti Mṙa no kyere̱ se wotw̌a pe̱ a e̱se̱ se̱ wo̱hyew se̱nea e̱be̱ye̱ na aba no mu yare no rensaṅ aba anā dua hõo̱deṅfo a aka no.

PLATE 6.

COLLAR CRACK OF COCOA

ROOT DISEASES.

NTINI AYARE.

1. There are four diseases, which attack the roots of cocoa trees, given in the Ordinance; they are Collar Crack, White Root disease, Brown Root disease and Collar Rot. Although, as we shall see, they differ from one another in appearance, their effect on the tree is the same. They kill the roots, and because a tree cannot live unless its roots are continuously taking in food from the soil, any more than a man could exist without a mouth to eat food, the whole tree must die. Death may be rapid or it may take some time, but it is bound to happen sooner or later. First we find the leaves wither and hang down, and then when they have died from loss of food the branches and stem also die. Now, when we notice a cocoa tree with its leaves hanging down as if they were tired of life, it is wise to examine the base of the tree and if we find nothing wrong there, to take away the soil from its roots and to see if there is anything the matter with them. If the roots are diseased it is better to dig up the tree entirely and to burn it rather than to leave it, because by burning it we shall kill the disease which otherwise would spread to neighbouring trees.

> 1. Ayare hrow anaṅ na e̱ye̱ kokō nnua no ntini se̱nea wo̱kyere̱ wo̱ Mra no mu no e̱ne; Dua ase mpāpāe (Collar Crack) Ntini yare fitā (White Root disease) Ntini yare dodowē (Brown Root disease) Dua ase pro̱wē̃ (Collar Rot). Ne nhinā sonsonõe se̱nea yehũ no de nanso ade a e̱ye̱ no nnua ho no se̱. Wokũm ntini no, na esĩané se̱ dua no ntumi nnyin gyese̱ e̱tw̌ẽtw̌ẽ asase no mu srade se̱nea e̱te wo̱ onipa hõ no se̱, onntumi ntrã ase gyēse̱ onyã ano de didi no ara pe̱, etw̌a se̱ dutaṅ no ṅhina wu nte̱m anā se̱ e̱kye̱ kakra nanso e̱ye̱ kakra a otw̌a na etw̌a se̱ ewu. Nea edi kaṅ no yehũ se̱ ṅhabaṅ no akagyaw na e̱sense̱n ho̱ na akyiri no se̱ aba no nnyã ade a e̱be̱ye̱ń no a dutaṅ no nso wu. Afei se̱ yehũ se̱ kokō ṅhabaṅ sense̱ń ho̱ na e̱ye̱ se̱ e̱rehodw̌ow anā e̱repo a, nyansã kwań a ye̱be̱fa so ne se̱ yefēfē dua no ase fw̌e̱, na se̱ ye̱ńhũ se̱ bribi adi bone wo ho̱ a yeyi ntini no so do̱te no na ye̱fw̌e̱ se e̱hõ akã ana? Se̱ ntini no ayare anāse̱ bribi aye̱ ntini no a eye se̱ yetu dua no korā na ye̱hyew na ense se̱ yegyaw si ho̱; efise̱ se̱ ye̱hyew a yebetu yare a se̱ yeanye̱ sā a ebekita nnua a akā ṅo.

COLLAR CRACK.

DUA ASE MPAEPAE.

2. If we examine the base of a wilted tree and we find cracks extending for a short way up the stem from the soil, we shall know that the tree is suffering from the Collar Crack disease. Under the soil the roots will also be found to be cracked as is shown in Plate 6, and both stem and root may be more or less rotten, so that

if we cut them through they will fall into wedge-shaped pieces. The cracks are filled by the white body of the fungus which projects beyond the bark and forms a yellow frill that soon becomes black. The tree which has been cut through and drawn at the top of the picture shows the fungus body in the cracks, which in three cases extend to the centre of the tree and cut off two wedge-shape pieces, these will soon be rotten and useless for conveying food to the leaves or stomach of the tree.

> 2. Se̱ ye̱fw̌e̱ dua a e̱repo ase a yebehũ mpāepae a efi dutaṅ no ase fro ko̱ soro kakra e̱nna ye̱de behũ se̱ dua ase mpāepae yare aye̱ no. Ntini a e̱wo̱ asāse no mu nso wobehũ se̱ apāpae se̱nea mfonini põṅ 6 no kyere̱ no, na dutaṅ no ntini no apro̱w pī anā kakrā, na se̱ yetw̌itw̌am' a emu pāpāe ntrāntrā ne̱ema fitafitā bi a efi ntuw no mu fw̌irew bõṅ no mu pue na e̱ye̱ nsensanee tese̱ ankāhonõ a e̱ṅkye̱ na edaṅ tuntum. Dua a wo̱atw̌am' no wo̱de nsa aye̱ ne mfonini wo̱ mfonini no atifī kyere̱ ntuw amā mre̱ (mre) no wo̱ mpāpae a akwaṅ abiesa so no e̱toaso̱ kosi dua no mfinimfini na e̱pae mu ntrantrā abien a e̱reṅkye̱ na apro̱-pro̱w a mfaso nni hõ, efisē entumi mfa nsu ṅko̱ nhabaṅ no anā dutaṅ no yafunu mu.

3. The bark is full of the roots of the fungus and gives the appearance when cut of being filled with mildew.

> 3. Dua no bõṅ no o̱yare no akata hõ na se̱ wutw̌a na wo fw̌e̱ a e̱ye̱ se̱ agye ntuw.

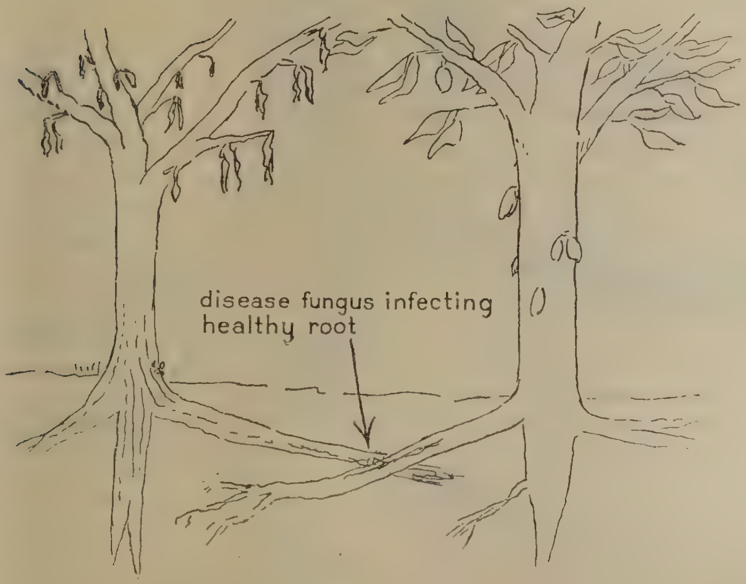
4. The fungus which causes the Collar Crack disease is a much bigger plant than the mildews that cause Pod diseases. It bears fruit, when the tree on which it grows is dead, that are like mushrooms with caps at first brown then becoming white with brown spots and brown stems; a group of the fruit are shown on Plate 6, drawn natural size. The seeds of the fungus are, however, even smaller than most of those of the Pod disease fungi; they are produced in very large numbers on the flat plates which hang under the cap.

> 4. Oyare a e̱mã dua ase paepae no ye̱ afifide ke̱se kye̱ń nyārewa a ekã kokō aba no. E̱sow aba bre a dua a enyiṅ wo̱ so no awu no e̱te se̱ mrẽ a mfiase no ne ti adow na akyiri no e̱dan fitā a dodowe sisi mu mfonini kuw a e̱wo̱ mfonini põṅ 6 so no kyere̱ senea e̱te pe̱pe̱pe̱. E̱to̱ dabi a o̱yare no aba susũae sẽn o̱yare a e̱kã kokō aba no mu pī, wobehũ aba no pī ara wo mrẽ no ase e̱ho̱ na enyiṅ na epae aba bebrē.

5. The fungus does not depend only upon seeds for its propagation; under certain conditions it can produce long black root-like strands which grow through the soil until they find another victim to which they cause the disease. And any old piece of wood or bark which contains some portion of the fungus body may

reproduce the disease when the material comes into contact with a living root.

5. Ọyare no ẹnnyẹ aba no ǹkõ so na ẹnam so fẹe, ọkwan bi so no etumi yi adi sẹ hama tuntum tẽã a ẹte sẹ ntini a enyin hyẹǹ dọte mu kosi sẹ ebenyã bribi akyere no de yare no asaǹ no. Na dufunũ anā dubõnã wui biara a ọyare yi wọ hõ no, sẹ ẹne ntini mõmõnõ hyia a etumi ma ọyare no saǹ no.



6. Probably the commonest method in this country, by which the fungus increases the number of cases of Collar Crack disease, is by growing along the root of a diseased tree until that root comes into contact with the healthy one of another tree, and the fungus hungry for the new food thus offered grows into and along the root of the healthy tree. So that in a short time a number of trees around the original case are found to be withering and dying.

6. Ebia ọkwaǹ a ọyare no tã fa so ma dua ase mpāpae yare dọsõ asase yi so ne sẹ enyiǹ wọ dua bi a ẹyare hõ kosi sẹ sa ntini no nè dua a ẹte apọw ntini hyia, na esĩane sẹ ọyare no fẃefẃẹ anyinye nti ẹtenẽ kọ dua a ẹte apọw no ntini no hõ. Sẹ̇ ẹba sā a ẹnkyẹ korā na nnua pī a kaǹ no ẹte apọw no repo na worewu.

7. It must be remembered that the fungus, which causes Collar Crack of cocoa, grows on a number of bush-trees and other plants and can give the disease to cocoa trees which grow in their neighbourhood, and that the treatment prescribed for dealing with Root

disease, which we shall consider later, should also be applied to any plant which bears the conspicuous fruits of the disease-causing fungus.

7. E̱se̱ se̱ ye̱kae se̱ se̱nea o̱yare no mã kokō dua ase pāpae no, saara na e̱ye̱ wuram nnua nè afifide fofro na etumi de yare no saṅ kokō mma a e̱bemme̱n hõ no, o̱kwań a wo̱akyere se̱ wo̱nam so tu sā ntini yare no a e̱renkye̱ na yebesusuw hõ no e̱se̱se̱ ye̱de to afifide bi ara e̱sow o̱yare aba a agyediṅ a e̱de yare a e̱mã ntuw ba yi hõ.

WHITE ROOT DISEASE.

NTINI YARE FITĀ.

8. The next root disease of cocoa given in the Ordinance can only be denominated by looking at the roots of a tree whose foliage has withered and is dying. If we find a white or pinkish cord attached to the root, creeping along them, and spreading about at the end into a white mildew, we know the disease is the White Root disease, and that the tree is doomed to death. The cord is the body of the fungus and sends its roots, which may be too small to see, into the roots of the cocoa tree.

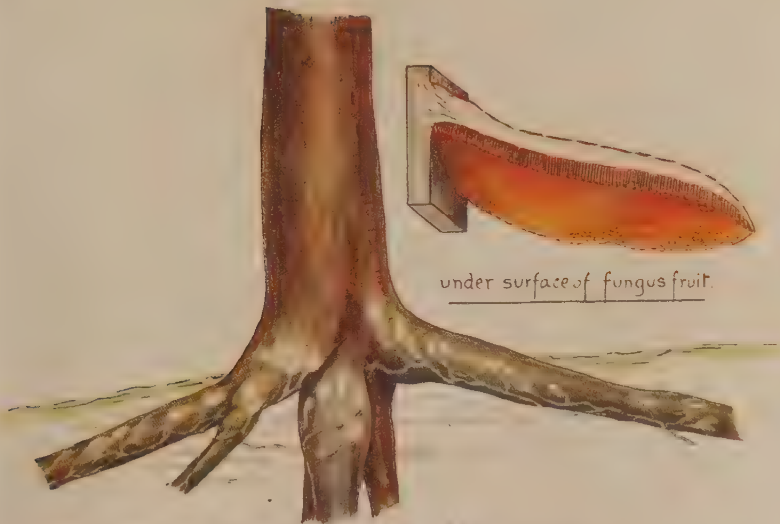
8. Kokō ntini yare fitā a edi so a wo̱kã hõ ase̱m wo̱ Mra no mu no nea wo̱de be̱to ne diṅ ara ne se̱ wobe̱fw̆e̱ dua a ne ṅhabaṅ akagyaw na e̱rewu no ntini. Se̱ yehũ hamā fitā anā kokō bi fra ntini no mu na e̱ne ne ṅhiṅa retẽntẽnẽ na e̱re̱ko̱ n'awiei a e̱daṅ o̱yare hama fitā a, yenim se̱ o̱yare no ye̱ ntini yare fitā, sā dua no edaṅ de̱ṅ ara a ebewu. Hama no nè o̱yare no ankasa na e̱di ntini a esũa no hye̱n kokō dua ntini mu.

9. The cocoa-root is killed by the fungus-roots and decays, but the fungus fattened by the food it has stolen from the cocoa tree goes on living and sends the cord through the soil in search of the roots of healthy trees in order to devour them. After the roots have been killed by the fungus, the leaves and stem of the tree are quickly starved to death. It is then that the fungus produces its fruit on the dead stump just above the soil. These fruit are shown on Plate 7, and will probably be recognised by most cocoa farmers as fungi they have seen on the stumps of old bush trees on their farms. They project from the stump like small shelves, the colour of a fully ripe orange on both their top and bottom surfaces. They are handsome in appearance with their bright colour, and appear to be harmless. But their under-surface consists entirely of innumerable little holes each one of which contains a large number of disease-seeds.

9. O̱yare no ntini no kũm kokō ntini na ma ewu na e̱nam nsu a e̱tw̆ẽtw̆ẽ fi kokō no mu no so nyã ahõo̱den do̱ srade na ntini no tenẽ wo̱ asase no mu fw̆efw̆e̱ nnua a e̱te apo̱w no ntini ase̱e no. Se̱ o̱yare no kũm ntini no w̆ie a dua no ṅhabaṅ twintw̆ãm na ewu. Sā bre no mu na o̱yare no sow

PLATE 7.

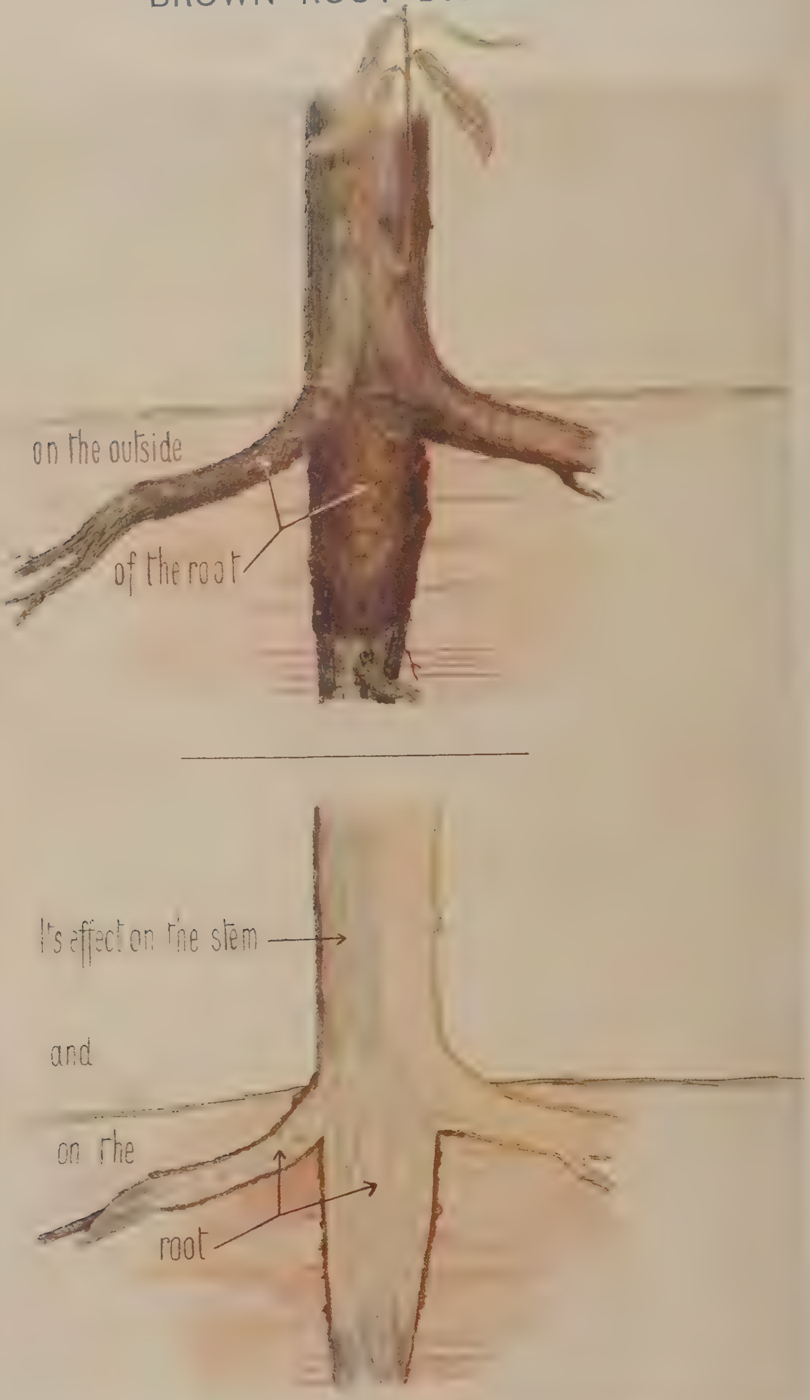
WHITE ROOT DISEASE



Roots of Cocoa Tree attacked by cords of the White Root fungus

Roots of the same Cocoa tree killed by the fungus which is now fruiting.

BROWN ROOT DISEASE



aba wo̱ dunsiṅ a awu a esi ho̱ no so. Sã aba yi yehũ wo̱ mfoninipõṅ 7 no mu na e̱ne nea kokō akuafo pī de behũ se̱ e̱ne o̱yare a wohũ wo̱ kwae mu nnunsiṅ a e̱wo̱ wo̱ṅ mfuw mu hõ no. Epue fi dunsiṅ no so se̱ ṅworā ṅketenkete wo̱ sro nè ase te se̱ akutu a abere wo̱ natifi nè ase ṅhinā. Se̱ wofw̌e̱ a e̱ye̱ fe̱ na e̱ye̱ hrãhrã na e̱te se̱nea entumi nse̱efw̌ē. Nanso ntokuru ṅketeṅkte pī hyehye̱ ase ho̱ a nyarewa aba pī ahye̱ mu mã.

10. The White Root fungus, like that of the Collar Crack disease, could manage to survive even if it never formed fruit ; any piece of diseased root contains the living fungus which can attack healthy roots, and as already explained the thread-like body of the fungus is capable of growing through the soil until it comes into touch with a healthy root along which it grows, and which it kills later on.

10. O̱yare a ni ntini hoa no te se̱ dua ase mpāpae yare se̱ annsow aba po a etumi ṅyiṅ eṅṅwu, ntini siṅ biara a e̱yare no etumi san ntini hõo̱deṅfo bi ara, na se̱nea wo̱akyere̱ mu dedaw no o̱yare hamã teā no tumi tenē fa asase mu kosi se̱ esõa dua hõo̱deṅfo no ntini na enyiṅ fa hõ a akyiri no ekũm dua no.

11. The fungus lives in the roots of many of the forest trees, it has even been found on Cassava, and generally when it is found in a cocoa farm careful search will show that it has come from an old bush stump. It is therefore necessary, when treating cocoa-trees that are attacked by the White Root fungus, to destroy also any bush-trees or stumps which bear the fungus, so that it may not do any more damage.

11. O̱yare no wo̱ kwaem' nnua pī ntini mu mpo wohũ wo baṅkye dua ase, na se wohũ wo̱ kokō afuw mu na wofw̌efw̌e̱ mu yiye a e̱bekyere̱ se̱ efi wuram' dunsiṅ de̱daw bi hõ. Eyi nti ehīa se̱ wo̱reye̱ kokō nnua a o̱yare ntini fitā no ase̱eno no aduru a, wotutu wuram nnua anā nnunsiṅ a e̱de yare no bae no se̱nea e̱be̱ye̱ na e̱rense̱e ade bio.

BROWN ROOT DISEASE.

NTINI YARE DODOWE.

12. Another root disease of cocoa, which cannot be named until the root is exposed to sight, is named Brown Root disease, because the fungus, which causes the tree to be diseased, consists of a brown soft material with a black hard skin in which pieces of soil and small stones become embedded. The fungus is closely attached to the skin of the root, and it very rarely appears above the soil. As it is slow in growth it may be slow in killing the tree and it is frequently found that one or two side-roots of the tree are completely rotted away before the fungus attacks the main root.

12. Kokō ntini yare fofro a wontumi nto ne diṅ gyē se̱ ntini no ada adi fãṅṅ ne Ntini yare dodowe ; efi se̱ ade a e̱mã dua no yare no mu wo̱ ade dodowe betē a w̌ere tuntum bi kata hõ a do̱te nè mmosea hyehye̱m'. O̱yare no fãm ntini no w̌ere hõ pī na e̱ntā nnyi ne hõ adi wo̱ asase ani. Se̱nea e̱kye̱

nyin no saara na e̱kye̱ ansã na ekũm dua no na no̱tã hũ se̱ dua no ase fa, se̱ ntini a e̱wo fa biako ana abieṅ pro̱w korā ansã na o̱yare no de akã ntuni ke̱se no.

13. The brown body of the fungus grows along and around the root of a tree until it comes into touch with the root of another tree which is healthy, it then begins to grow on the new root and after some time completely surrounds it; it is the fungus roots which kill the cocoa-root and cause a dry-rot of the wood. As it exhausts the food supplied by that part of the cocoa-root the fungus creeps up until it reaches the main root which in its turn is killed and rotted. The drawing at the top of Plate 8 shows what the fungus body looks like, and that at the bottom shows the same tree cut down the middle, by which it may be seen that with only one side root living, only a small portion of the cocoa tree remains alive, and that will soon be starved to death when the fungus has surrounded the still living side root and rotted that also.

13. O̱yare dodowe yi ho̱ fa dua no ntini hõ kosi se̱ e̱nè dua bi a e̱te apo̱w ntini hyia e̱fra ntini fofro no mu nyiṅ na bre bi akyi no e̱fa ntini fofro no di, e̱ye̱ o̱yare no ntini no na ekũm Kokō ntini no na e̱mã dua no kyēṅ na e̱pro̱w na esĩane se̱ e̱tw̌e nsu a ntini no nyã wo̱ sā bea ho̱ nti e̱tenẽ ko̱si kosi se̱ e̱be̱to̱ ntini ke̱se no, na akũm no. Se̱ wofw̌e̱ nsa mfonini no soro a wo behũ se̱nea o̱yare ne te. Nea e̱wo̱ ase no nso ye̱ dua koro no ara a wo̱atw̌am' abieṅ, e̱no na wode behũ se̱ ntini ketewā biako pe̱ nè kokō dua no fã kakrā bi na eṅwui e̱, na se̱ o̱yare no bare ntini ketewa a eṅwui no hõ hyia a, kokō dua no kagyaw na ewu.

14. Brown Root is a bad disease, it causes the cocoa tree to die, but it is not quite so dangerous as White Root disease which can go through the soil in search of new roots and can kill a number of trees in one spot; those killed by the Brown Root fungus are usually isolated.

14. Ntini yare dodowe ye̱ o̱yare bone a e̱mã kokō dua no wu eyi hõ nnye̱ hũ se̱ ntini yare fitā a etumi ko̱ fam akyiri pe̱ ntini foforo na etumi kũm nnua pĩ wo̱ brea a ntini yare dodowe tā kũm nnua ṅkoro ṅkoro.

COLLAR ROT.

DUA ASE PRO̱WĒ.

15. This disease is distinguished from the other root-diseases of cocoa by the fact that all the fungus body is contained inside the tree until the latter is dead and fungus fruits appear on its surface. Unlike the Collar Crack, White Root and Brown Root diseases, it has no part of the fungus body on the surface of the root.

15. Nea e̱mã e̱sõno sā yare yi ne kokō ntini yare horow a aka no ne se̱: o̱yare mũ no ṅhina hye̱ṅ dua no mu kosi se̱ ewu na o̱yare aba yi ne hõ adi wo̱ hõ. E̱nnte se̱ dua ase mpāpae ntini fitā nè dodowe yare no, eyi de o̱yare no nnyi ne hõ adi wo̱ ntini no so.

COLLAR ROT OF COCOA

16. The fungus which causes Collar Rot may attack either the roots or part of the stem. When it has entered the tree it slowly grows, killing the bark and wood as it increases in area. A little experience teaches a person to recognise the presence of the fungus by its effect on the wood which it kills and causes to become dry like tinder, and divided into small areas with thin black boundaries, so that if we cut through a root attacked by Collar Rot we shall see the appearance shown in the lower drawing on Plate 9.

16. O̱yare a e̱de dua ase pro̱wē ba no ekita ntini no anā se̱ dutaṅ no fã babi. Se̱ e̱hye̱n dua no mu a enyiṅ bere̱w na e̱remyiṅ na e̱rekum dubonã no ne dua no. Nsusuwhõ kakra be̱kyere̱ se̱ o̱yare no ade a e̱ye̱ ne se̱ ekũm dua no na e̱ma e̱wo daṅ ṅnyina (ogya) na emu pāpae nketeńkete a mpāpae no ano ye̱ tuntum na se̱ yetw̌a ntini no a dua ase pro̱wē akã no no a yebehũ se̱nea anim te se̱nea yehu wo̱ nsa mfonini 9 ase ho̱ no.

17. Sometimes only one side of the stem, or only one root is attacked, and as that part of the tree is killed and rotted, the other side of the stem and the other roots remain alive for some time. In which case only part of the foliage withers and dies. But it must be remembered that the whole will be killed ultimately although death may take some time. Soon after any part of the tree's stem is killed by Collar Rot, the fungus produces fruit on the surface of the bark; these fruits are at first small white knobs bearing on their surface innumerable numbers of very small white seed—the young fruits are shown on the right hand side of the upper drawing. When the fruit have reached maturity they contain a very large number of small vessels as is shown enlarged on the picture. These small vessels when ripe are full of disease seeds. This second kind of seeds are black and though they are much larger than the first kind that the fruits formed they are still small enough to get seven or eight on one of the printer's full-stops.

17. E̱to̱ dabi a dutaṅ no fã bākõ anā ntini bākõ pe̱ na o̱yare no kã no, na esĩane se̱ sā fã no nkõ na ewu anã e̱pro̱w nti dua no nè ntini no fã a aka no nyin bre kakra ara gyeṅṅ. Sā bre no mu no e̱so ṅhaban no fã kakra bi pó na ewu. Nanso e̱se̱se̱ ye̱kae se̱ e̱be̱kye̱ kakra ānsã na dua no awu. Se̱ dua ase pro̱wē no kũm dutaṅ no fã no w̌ie a o̱yare no sow aba wo̱ dubonã no anim sā aba yi efi ase apo̱wapo̱w ṅketeṅkete fitafitā, sā aba a ennyiṅa no wo be hũ wo̱ nsa mfonini a e̱wo̱ sro no nifã so. Se̱ aba no nyin a bribi ṅkruwa ṅkruwa nkete nkete fitã pī hyehye̱m se̱nea yehũ a wo̱aye no ke̱se wo̱ mfonini no mu no. Sā ṅkotoku ṅkete ṅkete yi se̱ e̱bre a o̱yare ahye̱ no mã. Sā aba hrow a e̱to̱ so abien yi ye̱ tũmm na e̱wom se̱ e̱sosõe seṅ aba a edi kaṅ no de nanso esusuae ara se̱nea asõṅ anā awotw̌e betumi ako̱ atintimfo osiw̌iei so.

TREATMENT PRESCRIBED FOR ROOT DISEASES.

O̱KWAṄ A E̱KYERE̱ SE̱NEA WO̱SA SĀ NTINI AYARE YI.

1. The Ordinance says we should dig out the entire plant that is affected by root disease, and then destroy it by burning, and after that the ground in which it grew should be isolated by digging a trench two feet deep all round the area where disease occurred.

> 1. Mra no kyere̱ se̱ yentu dua a o̱yare no aye̱ no mũ ṅhĩṅã nkyenẽ na ye̱ṅhyew, na e̱no akyi no asãse a enyin wo̱ so no yentu amõa a emu do̱ be̱ye̱ anamoṅ abien ntw̃a ofã a o̱yare no baa ho̱ no hõ nyhia.

2. If you remember how important the roots are to a tree you will readily understand that a disease which attacks the roots must sooner or later cause the death of the whole tree. If you will remember that a dead cocoa tree left in the ground will probably cause the death of its neighbours you will easily foresee the necessity of uprooting the diseased tree and of destroying the fungi, which cause root disease, by burning the tree.

> 2. Se̱ wo kae se̱nea ntini no hõ hĩa mā dua no a, wobe̱te ase nte̱m se̱ o̱yare a e̱kã ntini no bekũm dua no bre biara mu. Se̱ wo be̱kae se̱ kokō dua a awu a wo̱agyaw asi ho̱ no ampa ara ebekũm nnua a aka ho̱ no a wo be̱tease nte̱m ahũ nea enti a ehĩa se̱ wotu dua yarefo no na wo̱hyew de se̱e ntuw a e̱de ntini yare no ba no.

3. A dead cocoa-tree cannot bear pods, it is therefore useless to its owner—a dead cocoa-tree does cause death to other cocoa trees, it is therefore a danger on the farm—a cocoa tree suffering from root disease will be killed by the disease. Therefore Government says destroy the disease-causing fungi, and that is not a very difficult or costly thing to do.

> 3. Kokō dua a awu no ntumi nsow aba eyi nti e̱hõ nni mfaso mmã afuw wura no, kokō nnua a awu no kũm kokō nnua a aka no, eyi nti e̱de amane ba afuw no so. Kokō dua a ntini yare aka no o̱yare no bekũm no. Eyi nti Aban se̱ se̱e nne̱ema a e̱de kokō yare no ba no na sā ye̱ nnye deṅ nso adefw̃ere nnim'.

4. When we find the foliage of a tree withering, and see that its roots or collar bear one of the fungi that cause root disease, what we must do is to take up the soil from the roots, take out the roots, cut them and the whole tree up into pieces and burn them all.

> 4. Se̱ yehũ se̱ dua no ṅhabaṅ rekagyaw na ne ntini anā n'ase no asow nea e̱de ntini yare no ba no a nea e̱se̱se̱ ye̱ye̱ ne se̱ yeyi ntini no so do̱te na yeyiyi ntini no tw̃itw̃a e̱né dua mũ no ṅhinā asiṅasiṅ na ye̱hyew ne ṅhinā.

5. It must be carefully done, because if we have left any of the diseased material in the soil there is a big chance that it will grow and give the disease to healthy roots. Moreover a search should be made for the bush-stump or log which may have given rise to the disease, and that stump or log should be treated in the same manner. It will not be much use to remove the effect of disease only, the cause of the disease is the important thing to destroy.

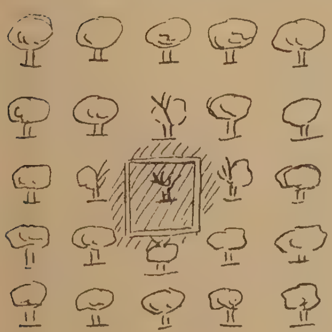
5. E̱se̱se̱ ye̱to ye̱n boase ye̱ no yiye efise̱ se̱ yegyaw siṅ no bi wo̱ fam a nea e̱be̱ba ne se̱ ebenyiṅ na e̱de yare no asan ntini a e̱te apo̱w no. Bio e̱se̱se̱ ye̱fw̌efw̌ē nnūfunũ anā nnisin a e̱wo̱ wuram a e̱de yare no bae no na ye̱ye̱ e̱nonom sāara. Se̱ yeyiyi ade a o̱yare no de ba nkõ ho̱ a e̱n'de e̱hõ nni mfaso pa bi, nea e̱de yare no bae ne ade titiriw a e̱se̱ se̱ yeyi no ho̱.

6. We have seen that most of the fungi which give root disease to cocoa trees can travel through the soil, either by themselves or by creeping along pieces of roots or sticks in the soil, and in order to prevent them from infecting healthy roots a 2-foot trench, over which they cannot pass, is cut round the diseased area.

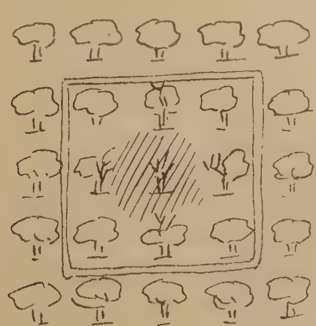
6. Ye̱ahũ se̱ o̱yare no mu dodow a e̱de kokō ntini yare no ba no kyin asāse mu, ebia e̱no ara anāse e̱fãm ntini anā nnua asinasin hõ wo̱ asāse mu na se̱nea e̱be̱ye̱ na ye̱remmã ennyã o̱kwaṅ nsaṅ ntini a e̱te apo̱w no nti wontu amõa a emu do̱ be̱ye̱ anamo̱ṅ abieṅ ntw̌a fākõ a o̱yare no wo̱ hõ ṅhyia na annyā kwaṅ antra.

7. There is, of course, a wrong way to make this trench as well as a right one and it would be wastage of time and energy to make too small a trench.

7. O̱kwaṅ pa nè kwaṅmone wo̱ ho̱ a wo̱fa so yi sā kã yi, e̱ne wuyi kã no ketewā a e̱nde wose̱e bre ne ahõo̱deṅ.



A



B

8. If the tree in the centre of the drawing A is suffering from root disease you may, or may not, find its near neighbours also attacked, which means that it is a waste of money to isolate that one tree, because the disease in the soil (shown by diagonal lines) would then be on the outside of the trench. It is far better to include even a few healthy trees within the trench as in B than to allow any diseased material to be outside the trench to infect the farm.

8. Se̱ ntini yare no akã dua a e̱wo̱ mfonini A mfinimfini no a ebia wobehũ anā woreṅhũ nnua a e̱be̱n no a o̱yare no akã wo̱ṅ ; eyi kyere̱ se̱ se̱ wuyi dua biako no fi nnua a aka no mu a wórese̱e sika efise̱ o̱yare a e̱wo̱ asāse no mu (se̱nea nsensanee a e̱beabea ho̱ no kyere̱ no) ebefi o̱kã no akyi. Eye korā se̱ nnua a e̱te apo̱w kakra be̱hye̱n o̱kã koṅtoṅ-kurow̌ no mu se̱nea B kyere̱ no se̱ṅ se̱ wo̱be̱ma nnee̱ma a o̱yare wo̱m' no akofi o̱kā no akyi na e̱de yare no aba afuw no mu.

DISEASES OF THE BRANCHES AND LEAVES.

ABÃ̄ NÈ ṄHABAṄ YARE.

1. We have spoken about the importance to the cocoa tree of the roots that supply it with raw food from the soil. The tree could no more produce pods without sufficient food than a man could do any kind of work without taking his meals. But if that man had no intestines to change his food into the blood which nourishes his body he could not exist, nor could a cocoa tree which had no leaves live on the food that its roots drink in. It must have sufficient leaves to change the raw food material into plant-blood, or, to digest its food (see drawing on page 19). If some of its leaves are diseased it can perhaps struggle along like a man with a diseased stomach, but it will not have sufficient energy to produce many pods. The more leaves it has that are healthy and doing their work well, the more pods it can produce; the bigger number of leaves that are diseased, the less pods it will produce.

> 1. Yeakyere̱ se̱nea ntini hõ hĩa kokō dua no se̱ e̱tw̃e srade fi asase mu de ma dua no. Se̱nea onipa annidi a onntumi nnye̱ adw̃uma biara no, sāara nso na dua no ntumi nsow gyēse̱ enyã aduaṅ. Na se̱ onipa nni nsõnõ a e̱be̱dán aduaṅ no aye̱ mogya a e̱yeṅ nipadua no a onntumi ntra ase no, sāara na kokō nnua a enni ṅhabaṅ no nam aduan ana srade a e̱tw̃etw̃ẽ fi ntini no mu no so nyiṅ. E̱se̱se̱ enyã ṅhabaṅ a e̱dōso ne e̱de ama aduan no adan mogya anase ye̱be̱kã se̱ e̱daṅ n'aduaṅ a odi. Se̱ ṅhabaṅ no bi yare a ebia ebetumi apre ne ńkwã anāse ebetumi akoṅkọṅ ho̱ te se̱ onipa a o̱yare aba ne yam; nanso o̱rennyã ahõo̱den nsow aba pī. Se̱ e̱wo̱ ńhabaṅ pī a ahõo̱deṅ wo̱m' a e̱n'de etumi sow pī se̱ e̱wo̱ ṅhabaṅ pī a e̱yare a e̱sow aba kakra.

2. The remaining diseases in the Ordinance are those which affect either the leaves or the branches which bear the leaves, and they must be regarded as serious, because they do diminish each year the number of pods which could otherwise be changed into cash.

> 2. Nyarewa a aka a wo̱kã hõ ase̱m wo̱ Mra no mu no ye̱ nea ekita ṅhabaṅ nè abã̄ a eyi ṅhabaṅ no, na e̱se̱se̱ yehũ se̱ sā nyarewa yi ano ye̱ den efise afe biara mu e̱mã kokō aba a e̱de sika ba no so hũaṅ.

3. Of all the diseases given in the Ordinance none are more easy to treat than are the four which remain to be described. In the case of the first three, White Thread, Horsehair, and Mistletoe, cut off the twig that bears them and burn the lot, and in the case of other plants growing on the trees, just pull them off and burn them. Surely it is worth while taking that little trouble to help the trees to make a good crop.

> 3. Nyarewa a Mra no kyere̱ no mu nea ne sa ye̱ mere̱w anā e̱nnye̱ deṅ ne anaṅ a aka a emu nkyere̱kyere̱ mu didi so yi. E̱de refa abie̱sa a edi kaṅ a eye̱ Hama fitā, nè tuntum yare ne Nyãṅkonuru (Krãmpã) hō no nea wo̱be̱ye̱ ne se̱ wotw̃itw̃a abã̄ a e̱wo̱ so no na wo̱hyew ne ṅhiṅa. Nea e̱fa afifide fofro a enyiṅ wo̱ dua so hõ nso, po̱npo̱ṅ e̱no nso na hyew. Ampara eye se̱ wohaw wo hõ kakra ye̱ sa ade yi se̱nea e̱be̱ye̱ na dua no be̱sow yiye.

WHITE THREAD.

HAMÃ YARE FITĀ.

1. Anyone who has been on a cocoa farm where the atmosphere is very moist, and has seen numbers of withered leaves which, although they are dead, are still hanging from the twigs, as is shown on Plate 10, will recognise this disease. It is much too common in a country like this where the wealth of the people so largely depends upon the good health of their cocoa trees.

> 1. Obiara a wakọ kokō afuw a a emu yẹ fọkyẽ mu pẹṅ na wahu ṅhabaṅ pĩ a agũaṅ, ẹwom sẹ awuwu de nanso ẹdaso seṅsẹn abã no so, sẹnea nsa mfonini 10 kyerẹ no behũ sā yare yi. Ẹtā ba asase a ẹte sẹ eyi a ẹsofo (ṅkrọfo) no nyã wọṅ sika (ahõnyãde) fi kokō a ẹte apọw mu no so.

2. The body of the fungus which causes White Thread disease looks like a dirty white cotton thread closely adhering to branches and twigs of cocoa or cola trees. It grows rapidly until it reaches the stalk of a young leaf and then divides into many branches, which send their roots into the leaf to feed on the blood of the cocoa tree that should go to the making of new pods. But it does more than that, it kills the leaves it feeds upon; and as it exhausts them it grows forward to attack the new leaves as they are formed. Look at the top branch in the picture. There are seven dead, and one almost dead, leaves killed by this leech-like fungus, which not content with the damage it has already done is beginning to attack the little shoot marked I.

> 2. Ọyare a ẹde hamã fitā yare yi ba no te sẹ asãwa fitā bi a ayẹ fĩ a ẹfemfam kokō nè bise nnua abã hõ. Enyin ntẹmntẹm kosi sẹ ebedu ṅhabaṅfro no ase na eyiye abã pĩ de ne ntini no hyẹn ṅhabaṅ no mu tw̃ẽtw̃ẽ kokō dua no mu nsu a ẹsẹsẹ ẹkọyẹ aba no. Nanso ẹyẹ nea ẹsẽṅ sā, ene sẹ ekũm ṅhabaṅ a edidi mu no na sẹ emu aduaṅ sa a enyin ko n'anim de kokō ṅhabaṅ a ẹrefefẹw fofro no. Fw̃ẹ abã a ẹwọ mfonini no sro no mu na wobehũ sẹ emũ ṅhabaṅ asõṅ awuawu, na bākõ reyẹawu, ṅhabaṅ a ọyare a ẹte sẹ amemem a nea wasẹe dedaw no anso n'ani no refi ase atoa abã ṅketewa no sẹnea wọde agyirae yi I kyẹrẹwọ mfonini no mu no.

3. The fungus produces a large number of very small mushroom fruits on the leaves it has killed, and though these fruit are hardly so big as an infant's finger-nail they each bear a number of disease-seeds. But probably the commonest way by which it increases its thieving work is by growing from one leaf to another, as is shown at the spots marked II and III on the plate. It does not matter whether the foliage of a tree attacked by White Thread is actually touching the leaves of another tree, the fungus on a fallen

WHITE THREAD

I Disease attacking young shoot

II Diseased leaf giving disease to healthy leaf

III Fallen leaf giving disease to healthy leaf.

leaf frequently carries the disease to other trees by being blown there by the wind as is shown at the spot marked III.

3. Ọyare no fifi mmẽrẹ aba ṅketeṅkete pĩ wọ ahabaṅ a akũm no no so, na ẹwom' sẹ aba yi nnu akokoã bow̃erẹw de nanso emu biara sow aba a ọyare wọm' pĩ. Nanso ọkwan titriw a ẹnam so terẹw ne hõ mu ne sẹ ew̃iaw̃ia ne hõ kọ ṅhabaṅ no so sẹnea mfonini no mu fa II & III kyerẹ no. Sẹ dua kõ a sã hama fitã yi nẽ ne ṅhabaṅ di asi no kọkã dua fofro ṅhabaṅ po a ẹnnyẹ fw̃ẽ, ọyare a ẹwọ ahabaṅ a atọ fam no so no nam mframa so de yare no kọ nnua fofro so te sẹ babia wọakyerẹw họ III no.

4. The cocoa-tree is defenceless against this enemy; consider how valuable the foliage is to the tree, and how valuable the tree is to the farmer; is it not strange that the white-thread fungus should be found on any farm in this country?

4. Kokõ nnua no ntumi nè sã ọtamfo yi nni asi: susuw ṅhabaṅ no hõ sẹnea ẹhõ hĩa ma okuafo no, so ẹnnyẹ ṅwonwã sẹ wohũ ọyare hamã fitã yi wọ asase yi so mfuw mu?

HORSE-HAIR BLIGHT.

HAMÃTUNTUM YARE.

1. Let us think what the long black hairs of a horse's tail would look like if a number of dead and dying cocoa leaves were entangled by them, and we shall recognise this disease called Horse-hair Blight. Plate II shows what it looks like.

> 1. Mommã yensusuw ǫpǫ́nkǫ dua hõ ǹw̃ĩ (ǹhw̃i) tuntum hõ na yebehũ sę sę kokō ǹhabaǹ a awu anāsę ęrewu bęfram' a ęn'na yebehũ ǫyare a wǫfrę no hama tuntum yare yi yiye. Mfonini põǹ II kyerę sęnea ęte.

2. The fungus which causes the damage is a close relative of the White Thread fungus, but if we call the latter a leech we should call the horse-hair fungus a python (nini) that squeezes its victims to death. The long black shining strands are the fungus body and the very small mushrooms which may sometimes be found on them are its fruits.

> 2. Ǫyare a ęde sā sęe yi ba no kow̃iew̃ie hamã fitā yare yi na sę yęde ęno to amemem hõ a, en'de yęde hamã tuntum no yare no nso bęto nini hõ sę omĩa aboa a wakyere no no kosi sę owu. Hamã tuntum hanãhanã no ne ǫyare no ahamã na mmẽrę ǹketeǹkete a ęto dabi a wohũ wǫ se no ne emu aba.

3. Now the leaves of a cocoa tree cannot do their work unless they have plenty of air and light, any more than a woman could cook food without fire, and the damage done by horse-hair to cocoa trees is caused as much by entangling the leaves together, so that they get neither sufficient air nor light, as much as by their ultimate death.

> 3. Afei kokō dua so ǹhabaǹ no rentumi nnyę n'adw̃uma yiye gyẽsę enyã mframa nè haǹǹ pĩ sęnea ǫbea renntumi nnõa aduan gyẽsę wanyã ogya ansã no, ǫsęe a hama tuntum yare de ba kokō dua so no, nea ęnam so ba ne ǫtõa a ętõatõa kokō ǹhabaǹ no ǹhiǹã na ęmmã ennyã mframa nè haǹǹ a ęsę no, aw̃iei no ede owu ba.

4. The fungus is a bad enemy to cocoa, but unlike the White Thread fungus it is only occasionally affixed to the leaves and twigs, and therefore is more easily removed.

> 4. Ǫyare yi yę kokō tamfo kęse nanso ęntesę Hamã fitā yare no, ętǫ dabia ęfãm ǹhabaǹ no nè abã hõ a enti ne yi nnyę yi nã.

HORSE-HAIR BLIGHT

LORANTHUS PARASITIC ON COCOA

LORANTHUS (MISTLETOE).

NYAṄKŌNURU (KRÃMPÃ).

1. All of the foregoing diseases are caused by the small plants we call fungi, but this one, as everybody knows, is caused by a plant which has green leaves, and flowers as well as fruit.

1. Nyarewa hrow a edi anim no nhinā nea ẹde ba ne afifide ṅketeṅkete bi a wọfrẹ no ntuw na eyi de sẹnea obiara nim no ne ede ba ne afifide biá ne ṅhaban yẹ ahabamonõ su a egu nfw̃ireṅ na ẹsow aba.

2. Mistletoe cannot be considered as an honest plant that works for its own living, because it makes use of cocoa, and many other kinds of trees to supply it with food ; it is a parasite like the ticks are on cattle.

2. Wonntumi ṅṅka sẹ Nyankõnuru (Krãmpã) yẹ dua pa a ẹde ne hõ, efisẹ kokō ne nnua pī mu na etw̃ẽtw̃ẽ nsu fi. Edidi nnua hõ sẹnea sõmmọre yẹ ntọteboa hõ no.

3. The upper picture on Plate 12 shows a young mistletoe plant which has established itself on a young cocoa branch ; you will notice that the cocoa branch is healthy, and that the parasite has no roots connecting it with the soil, it must therefore depend on the roots of the cocoa-tree to supply it with its raw food material from the soil. As the mistletoe grows it requires more and more of this food, and consequently the end of the branch on which it grows gets less and less, and the result which must happen is that the branch dies, as is shown in the bottom picture. If we cut through that part of the mistletoe which ought to be its root, we shall see clearly how the wood or gullet of the parasite is joined to the wood or gullet of the cocoa tree, and how it is starving the end of the branch with its leaves, and perhaps pods, to death. Now whilst the mistletoe is taking away from the tree its raw food it is doing nothing for the tree in return ; it has green leaves which digest the raw food stolen from the cocoa-tree, but it uses up the plant-blood so made for its own purposes only, and so it kills the branch on which it grows.

3. Yẹfw̃ẹ mfonini 12 no soro a yehũ Nyankõnuru (Krãmpã) a agye agua wọ kokō aba a ennyini a ẹwọ ahõọden so, na aw̃ekwa no nni ntini a eso asase mu enti etw̃a na etw̃a sẹ ẹdaṅ kokō ntini na ẹde nsu a enyã fi asãse mu no yẹn no. Nyaṅkõnuru no renyin no ẹfw̃efw̃ẹ sã aduan yi pī na nea ẹba ne sẹ abã a enyin wọ so no ase kọsi sũa dã na nea efi mu ba ne sẹ dubã no wu sẹnea yehũ wọ mfonini a edi ase no mu. Sẹ yẹpae Nyaṅkõnuru no fã a ẹsẹ sẹ ẹyẹ ntini no mu a yehũ pefẽ sẹ ne dua anãse menewa a ẹda mu no nè kokō dua anãsẹ menewa no abọm' na ẹde ọkọm rekũm kokō no abã nè ne ṅhabaṅmpo n'aba no. Afei bre a Nyaṅkõ-

nuru (Krãmpã) yi regye dua no mu nsu yi ennye fwē mmã dua no ewo ahabañ mõmõnõ a edi aduan momõnõ a eẘia fii kokō dua no mu no na esĩane se sã afifide mu nsu anã srade no ode ye nañkasa hõ ade nti, ekũm abã a enyiñ wo so no.

4. Mistletoe is a thief who steals from the cocoa tree and consequently from the farmer ; if the farmer is wise he will cut off all branches which are occupied by this thief, and cast him into the fire before the tree is completely taken over. Mistletoe, having no other work to do, produces a large number of red flowers, which in their turn give rise to fruit containing seeds. These fruits are eaten by birds, and the seeds, which adhere by their stickiness to the birds' beaks, are carried to the branches of other cocoa trees and rubbed off. In a short time the seeds germinate and, instead of producing an honest hard working root-system, they form a sucker which penetrates the wood or gullet of the cocoa tree, and the thieving parasite begins to destroy the tree.

4. Nyañkõnuru (Krãmpã) ye oẘifo a oẘia kokō dua no mu ade na enti owia okuafo no ade. Se okuafo no nim nyansã a obetẘa abã a oẘifo yi gye afa yi na ode ato gyam' ahyew ansã na wagye dua mu no ñhinã. Nyañkõnuru a onni fẘē ye no gu ñfẘireñ ñkoko pī na eno nso asañ asow aba. Sã aba yi nnõmã di, na aba a emũ nsu ye tẘã no ka nnõmã no ano na wode kotẘitẘiw kokō nnua hõ. Enkye kora na aba no afifi na senea añka ebebre hõ agye ntini asase mu no ekofãm dua no hõ fẘirew dua no nè emu furu mu na afifide ẘifo yi fiase see dua no.

5. No real cocoa farmer ought to pass by a cocoa tree bearing mistletoe without killing the thief. Cut off the branch that bears it and burn it as it deserves.

5. Obiara a obu ne hõ se kokō kuafo pa no ense se otẘa kokō dua a Nyañkõnuru siso hõ ko a ontore sã ẘifo yi ase. Tẘa bã a esi so no na nea ese ara ne se wo hyew.

EPIPHYTES ON COCOA TREE

EPIPHYTES ON COCOA TREES.

AHUM NÈ AHAM.

1. The last of the injurious pests to which the Ordinance refers are called epiphytes, because they are plants which grow not in the ground but on the surface of other plants. They differ from mistletoe because they do not take anything but support from the tree on which they grow. None of them has a sturdy body to lift it up into the air and light, and so they seek a tree like the cocoa to raise them out of the deep shade on the surface of the ground.

> 1. O̱yare bone a edi akyiri Mra no kã hõ asẹm no wofrẹno Ahum-nè-Aham efisẹ ẹyẹ afifide a ennyiṅ wo̱ asase so na mmom enyiṅ wo̱ afifide binom so. Ẹsonõ ẹno na ẹsonõ Nyaṅkõnuru (Krãmpã) efisẹ ennye bribiara mmfi dua no ṅkyẹn. Wonni dua a esi pim a etumi mã so ko̱ ahum mu nè hann mu enti wo̱fw̃efwẹ dua a ete sẹ kokō na amã woṅ so afi onw̃ini mu wo̱ asase ani.

2. There are many different kinds of plants, which have this nature, to be found in a cocoa farm and in the bush ; eleven different ones are shown on Plate 13. They take in nourishment from the bits of dead vegetable matter which occur on the rough bark of the tree, and from the moist atmosphere which surrounds them.

> 2. Afifide hrow pĩ wo̱ ho̱ a ekura eyi su a wo hũ wo̱ kokō mfuw nè wuram'. Ẹnam ahorow dubiako wo̱ mfonini 13 no mu wo̱tw̃ẽtw̃ẽ nsu fi afifide a awu a ẹwo̱ nnua hõ abõṅ nè foṅw̃ini a atw̃a hõ ahyia no mu.

3. Epiphytic orchids bear flowers, but mosses and ferns which are also epiphytic do not.

> 3. Ahum-nè-Aham no sow ṅfw̃iren nanso dua hõ nw̃ĩ nè mmẹyā (aya) a ẹyẹ o̱yare koro no ara bi no de eṅṅu ṅfw̃ireṅ.

4. Now these epiphytes do not take food from the cocoa tree as parasites do ; they never get inside the body of the cocoa tree as do the fungi which we have been talking about ; and the cocoa-tree is strong enough to bear the weight of more than would have room to grow on it. What harm can they do ?

> 4. Afei sā soro nnua yi nnye nsu mfi kokō dua no mu sẹ aw̃ekwa anāsẹ Nyaṅkõnuru yẹ no, ẹnnhyẹṅ kokō dutaṅ no mu sẹnea o̱yare a yeaka hõ asẹm no yẹ no, na kokō dua nso wo̱ ahõo̱den sẹnea ẹsẹ a ebetumi asoa dodow ara a ẹyẹ duru kyẹn nea ebetumi annyin wo̱ so. Bone bẹn na ẹyẹ ?

BULLETIN No. 12.

Department of Agriculture,
Gold Coast.

Cotton Pests of Southern British Togoland and Trans-Volta District.

BY

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PLATE I.

THE COTTON AREAS OF SOUTHERN BRITISH TOGOLAND AND, THE TRANS-VOLTA DISTRICT OF THE GOLD COAST COLONY.

PRESENT COTTON AREAS.

POTENTIAL AREAS.

FIGURES IN RED INDICATE MEAN ANNUAL RAINFALL IN INCHES.

Reproduced at Survey HQ. Accra 1927.

INTRODUCTION.

IN parts of what is now British Togoland and in parts of the Trans-Volta district of the Colony the cultivation of cotton has been practised for many years by the African farmer, the lint being used locally for the weaving of native cloths. Attempts have been made during recent years to increase the amount of cotton grown and establish an export industry. So far these attempts have not been so effective as was anticipated owing to the poor yields obtained, largely due to the attacks of insect pets. Attempts have been been made to introduce varieties of better yielding and better lint-producing cottons but up to the present these have proved abortive chiefly owing to the attack of insects, attack being particularly prevalent on exotic varieties.

The potential cotton growing areas of British Togoland are confined to those between the ranges of hills where open grass or orchard bush and transition forest occurs and on the southern plains where there is the necessary population. In the Trans-Volta district of the Colony a large area exists behind the Keta lagoon.

The experimental work outlined in this paper was carried out at (1) Abor, behind the Keta lagoon, at (2) Kpedsu, representing the southern plains of Togoland, and at (3) Ve, representing the orchard bush and transition forest areas between the mountain ranges 60 miles further north, in which most of the present export crop of to-day is grown. At the former two places Departmental experimental stations exist and records were obtained on these. At Ve records were obtained from native owned farms. At the latter place it has been known for some years that the usual insect pests prevalent in other areas are conspicuous by their comparative absence and the one object in taking records here was to ascertain the reason.

The Cotton Pests of Southern British Togoland and Trans-Volta District of the Colony, with Particular Reference to the Cotton Stainers, *Dysdercus Spp.*

PART I.

The present cotton areas are shown in the accompanying map and the potential areas where development may take place are also shown. The export of 487,343 lbs. in 1925-26 has almost entirely originated from two districts, the chief of these being the areas comprising the Ve, Hohöe and Kpandu divisions, and to a lesser extent, from the Adaklu division further south. Cotton is grown, however, to a small extent in all open populated areas, inter-mixed with food crops, and spun locally.

Little is known about the varieties at present grown by the native farmer. These varieties were distributed under the German administration previous to 1914. In the Adaklu division local varieties known as "Sonko," "Kadeanyigba" and "Deti Je" are grown. "Sonko" is apparently what was distributed by the Germans as Togo Sea Island, and "Kadeanyigba" as Upland. "Deti Je," a brown cotton, is now very rarely seen, and "Kadeanyigba" is not liked by the native farmer on account of it being difficult to gin and spin by the ordinary native methods. "Sonko" is therefore the prevailing variety. Further north, in the Ve, Hohöe and Kpandu divisions, the prevailing variety is a "kidney" cotton but otherwise similar to "Sonko." This latter variety is gradually being replaced by an improved Nigerian variety known as "Ishan." On two of the Departmental Stations tests have been made with "Allen" cotton, an American variety, seed of which was obtained from Nigeria. This variety is being advocated for the Northern Territories of the Colony where it is not subject to the attacks of pests to the same degree.

During the present investigations it has been found that the same varieties of cotton grown in Southern Togoland are subject to the attacks of pests, particularly cotton stainers, to different extents dependent on the area in which they are grown, this being due partly to the occurrence or non-occurrence of certain alternative food-plants and partly due to differences in behaviour of the same varieties of cotton in different localities. It is proposed therefore to give some idea of the type of country and the differences in climatic conditions in the different areas in which cotton is now grown.

Type of Country.

The country south of a line drawn from Adidome to Dsoje on the Anglo-French boundary and north of the Keta lagoon consists of open undulating grass country with a considerable depth of soil. The Baobab, *Adansonia digitata,* is the commonest tree, particularly at Adidome and Abor. North of this line and extending up to the Togo Mountain Range the country is sparsely populated on account of lack of water in the dry season except in isolated areas along the River Todsche and on the lower slopes of Adaklu mountain. Silk Cotton trees, chiefly *Eriodendron,* occur thickly along the river beds and nullahs, and in swampy regions. On the slopes of Adaklu Mountain, the Ahunda Hills and on the Eastern slopes of the Togo Range, *Eriodendron* and *Bombax*, particularly the latter, occur comparatively densely. *Adansonia* also is comparatively dense on the lower northern slopes of Adaklu Mountain, and also occurs occasionally throughout the plains. The Togo Range, extending from the Volta River near Senkye in a north-easterly direction, is covered with deciduous forest extending far down on the western side and at the base of the western slopes. *Eriodendron* and *Bombax,* particularly the latter are common. From Logba, southwards, at the base of the western slopes of this range, *Adansonia* is also common. The open country west of this range and extending as far as the Kpandu range consists of orchard bush and open grass country in which the river beds are lined with *Eriodendron*. *Adansonia* is again comparatively common at the base of the Eastern and Western slopes of the Kpandu range.

Throughout Southern Togoland and the Trans-Volta district *Adansonia* occurs in clumps near villages suggesting that it was originally planted for shade and possibly medicinal purposes.

Climatic Conditions.

Since the German administration no meteorological records have been taken north of the Togo Range, and those taken south cover too short a period to be of any value. However the rainfall figures taken from 1905 to 1913 under the German administration are available for reference (1). These records definitely show that the rainfall is considerably higher north of the Togo Range than south and that the small rains in September and October are more pronounced. Observations over the last few years indicate that north of the range the dry season and "harmattan" are considerably more marked. These factors appear to have an important bearing on the late production of bolls in the Ve, Hohöe and Kpedsu districts and the shortness of the fruiting season.

Humidity at Kpedsu, Ve, and Abor during the 1926-27 season is shewn in Graphs 1 to 4.

Insect Pests Attacking Cotton.

The following is a list of the various insects attacking cotton in the Gold Coast and British Togoland.

Attacking Foliage.

Aphis gossypii. fam. Aphidae. Adults and nymphs live and breed on the lower surface of the leaves and cause damage by sucking, resulting in leaf-curl and ultimate abscission. They are controlled naturally by the larvae and adults of two Coccinellids, *Chilomenes lunata.* F., C. *vicina,* Meds., and the larvae of the Syrphid fly, *Ischiodon scutellare.* F. which are predaceous on the colonies.

A Jassid, probably *Empoasca fascialis.* The adults and nymphs live and breed on the lower surface of the leaves causing hardening and ultimate abscission. Both Aphis and Jassid follow poor soil conditions.

Sylepta derogata F. fam. Pyralidae. The larvae of this moth feed on the leaves rolling them up for protection; hence the name " Cotton Leaf Roller ". Not serious. The larvae are heavily parasitised by a Braconid.

Helopeltis bergrothi Reut. fam. Capsidae. The adults and nymphs suck the shoots and petioles. Occasionally a serious pest before bolling commences. They disappear as soon as the dry season sets in.

Apate monachus F. fam. Bostrychidae. Occasionally found in isolated patches attacking the stems of cotton plants at the end of the dry season when formation of new bolls has ceased. Not serious.

Attacking Roots.

Syagrus calcaratus F. fam. Eumolpidae. The larve of this beetle live on the developing roots of cotton causing on occasions considerable damage. The attack is more serious on exotic cottons than native varieties, apparently owing to the latter having greater power of root recovery. An acre of exotic cottons grown in a variety test at Kpedsu was completely destroyed by the larvae of this beetle during 1926-27. Native cottons suffered to a lesser exent The larvae appear to depend on damp soil conditions for their existence although at Kpedsu they survived the dry season.

Attacking Bolls.

Dysdercus spp., fam. Pyrrhocoridae. The well known Cotton Stainers. Damage is caused by the nymphs and adults sucking the unopened bolls and introducing Internal Boll Disease resulting in abortion of one or more locks or staining of the lint. Damage is not caused by the nymphs and adults excreting on the lint as was thought at one time. The bionomics etc. of these insects are detailed later in this paper.

Two species of Melolonthid beetle, probably *Pachnoda* spp., are occasionally found eating the pericarp of developing bolls usually at the base. Damage invariably results in shedding of the attacked boll. The beetles are as a rule not common.

Earias biplaga Wlk. and E. *insulana* Boisd: fam. *Noctuidae* The Spiny Bollworms of Cotton. The larvae of these moths are the commonest bollworms of cotton in Togoland and the Trans-Volta District. Early in the season, when bolls have not commenced to set in quantity, the larvae are shoot borers. Eggs are laid singly on the bracts of developing shoots, the young larvae hatching out and destroying the developing shoot, afterwards boring for a short way down the stem. Latter, when the bolls are setting in quantity, the eggs are laid on the bracts of bolls, the young larvae afterwards boring into the unopened boll and destroying the seeds. Damage is serious as one larvae does not confine its attention to one boll but moves on from boll to boll until full grown.

Argyroploce leucotreta Meyr. fam. Eucosmidae. The larvae of this moth are primarily scavengers confining their attention chiefly to bolls that have opened prematurely either due to stainer injury or the attack of *Earias* spp. Ocasionally they are found attacking green unopened bolls but this is uncommon. Pomeroy (2) states that at Moor Plantation in Southern Nigeria during the 1924-25 season this was the commonest bollworm. It must therefore be regarded as a potential pest.

Diparopsis castnea Hamps. fam. Noctuidae. The larvae of this moth damage unopened bolls in the same way as *Earias* spp. but as a rule attack is confined to one boll only per larva. After considerable investigation this bollworm has been found not to occur in Southern Togoland or in the Trans-Volta district of the Colony. It is apparently common in the Northern Territories of the Colony.

Prodenia litura F. fam. Noctuidae. The larvae of this moth are occasionally found attacking green bolls but are exceedingly uncommon.

Attacking Seeds.

Oxycaraenus spp. fam. Lygaeidae. The adults and nymphs of this bug suck the seeds of cotton just after the bolls have opened. No damage is caused to the lint but devitalization of the seeds results. They are also common on freshly opened silk cotton pods.

Pyroderces simplex fam. Pyralidae. The larvae of this moth eat the seeds of freshly opened bolls and also cotton seed in storage. Common on " kidney " cotton. Not a serious pest.

Mometa zemiodes Durr. fam. Gelechidae. Cause similar damage to *Pyroderces simplex*.

PART II.

THE LIFE HISTORIES AND HABITS OF THE MAJOR PESTS OF COTTON.

Cotton Stainers Dysdercus Spp.

There are three species of *Dysdercus* which attack the ripening bolls of cotton in the Gold Coast. These are *Dydercus superstitiosus* F., *D. nigrofasciatus* Stall., and *D. melanoderes* Kand. Of these *D. superstitiosus* is by far the most important.

Description of Species.

Dysdercus superstitiosus F.—Head, antennae and legs dark red. Prothorax and anterior half of hemelytra yellow. Each hemelytron bears a black bar extending across the elytra in the non-migratory form, to a small spot in the migratory form. Abdomen banded in red and white.

Dysdercus nigrofasciatus Stall.—As *D. superstitiosus* but with black markings on the ventral surface of the distal abdominal segments.

D. melanoderes Kand.—General colour yellow green with no markings on elytra.

Occurrence.

D. superstitiosus is the commonest species in British Togoland, the spotted migratory form being most predominant at the beginning of the season i.e. September to November, and the banded when breeding on cotton is at its height. In localities where alternative food plants are numerous, particular the Baobab, *Adansonia digitata*, the banded form predominates throughout the cotton season.

D. nigrofasciatus and *D. melanoderes* were only occasionally collected from cotton during the season.

Life History.

The life histories of the different species of *Dysdercus* are similar, and have been worked up in detail in most countries where they occur. In Nigeria Pomeroy and Golding (3) have worked up the life-history of *Dysdercus superstitiosus* in detail and the following is a summary of their records.

Pomeroy and Golding observed that the average period from copulation to first oviposition was $5\frac{1}{7}$ days and between ovipositions four days. The average number of eggs in consecutive ovipositions was as follows :—

1st.	2nd.	3rd.	4th.	5th.	6th.
70	67	60	58	58	46

The average number of eggs laid by one female was found to be 237, the minimum 70 and the maximum 462.

The average period of incubation was found to be $5\frac{1}{2}$ days.

Table I taken from Pomeroy and Golding's paper gives the nymphal instar periods.

TABLE I.—LIFE-HISTORY OF DYSDERCUS SUPERSTITIOSUS.

Instar.	No. exps.	Average No. of days.	Minimum No. of days.	Maximum No. of days.
1st	203 ..	3–4	2–3	7–8
2nd	115 ..	4–5	3–4	9–10
3rd	79 ..	4–5	3–4	11–12
4th	66 ..	5–6	3–4	8–9
5th	65 ..	8–9	5–6	12–13
Total No. of days..		24–29	16–21	47–52

These workers found the average longevity of the adults from final ecdysis, i.e. moult, to death to be 25 days in the case of males, and 21 days in the case of females, the maximum period being 48 and 44 respectively. They also showed that there was no apprecia-ble difference in the period of adult longevity at the beginning of the cotton season and at the end.

The eggs are laid in batches in cracks in the grounds and under rubbish. They are spherical in shape and light green in colour when new laid turning to brown as the incubation period advances. The newly hatched nymph is orange in colour and has not been observed by the writer feeding on cotton bolls at this stage. The second instar nymph resembles the first but is brick red in colour and larger. In the third instar the wing lobes appear as small black triangles on the thorax. In the fourth and fifth instars these wing-lobes become successively larger. (see Plate II Figs. 1-7).

In Togoland, etc., during the dry season, conditions become too arid for breeding on the cotton fields themselves and the adults and fifth instar nymphs migrate to more favourable food such as fruiting silk cotton in the neighbourhood.

PLATE II.

Fig. 1. Eggs.

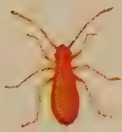


Fig. 2. First instar nymph.

Fig. 3. Second instar nymph.

Fig. 4. Third instar nymph.

Fig. 5. Fourth instar nymph.

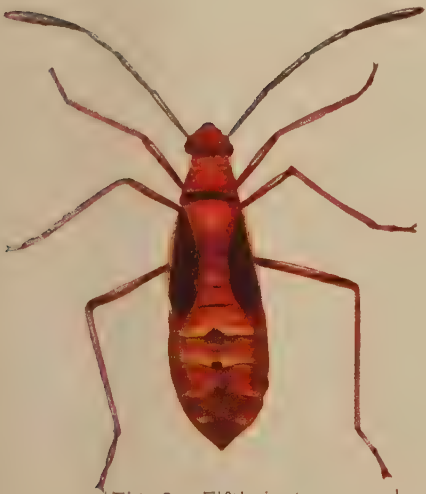


Fig. 6. Fifth instar nymph.

Fig. 7. Adult.

The Red Cotton Stainer. Dysdercus superstitiosus. F.

PLATE III.

Fig. 1. Nymph of Phonoctomus fasciatus. P.B.

Fig. 2. Phonoctomus fasciatus. P.B.

Fig. 3. Head of P. fasciatus.

Fig. 4. Bogosia pomeroyi. Vill.

Fig. 5. Dysdercus superstitiosus with eggs of Bogosia pomeroyi on leg and abdomen.

No egg parasites of the cotton stainer have been observed either here or in Nigeria. One species of Tachinid fly has been bred out in Togoland from the final instar nymph, namely, *Bogosia pomeroyi* Vill. The eggs are laid on the legs, side and top of abdomen under the elytra of the adult. Only a small percentage of stainers infested with eggs become actually parasitised owing to the difficulty of the newly hatched larva obtaining immediate ingress to the host. Of a large number of adults collected throughout the season in Togoland an average of only 6.5 per cent were observed to be infested with eggs. However, as many as from 20-25 per cent were found to be infected at the beginning of the season during the first migration to cotton. A feature of this parasite was the small number of nymphs that were found infested with eggs on the cotton field, *i.e* 0.5 per cent. In January and February, when a number of silk cotton trees were in fruit and which were being kept under observation, adults and nymphs were observed feeding on the fallen fruits in considerable numbers. The adult flies of the parasite were observed standing on surrounding weeds waiting to pounce on the back of an adult or nymph and oviposit. From a census taken of infested nymphs in this situation it was found that approximately 20 per cent had Tachinid eggs laid on all parts of the body including the head and antennae. These trees were fruiting during the dry season when breeding had ceased on cotton fields in the vicinity. The adults had migrated and were breeding on silk cotton seeds where conditions were more humid and shaded.

The high percentage of nymphs infested compared with the low percentage on the cotton fields when breeding was at its maximum, is accounted for by the fact that the adult flies of this parasite prefer shaded and more humid situations than what generally occur on the cotton fields. Such conditions naturally occur under silk cotton trees growing in the vicinity of swamps and river beds. The comparatively high percentage of infested adults on the cotton field is probably due to their having become infected with eggs when sheltering in surrounding bush during the heat of the day.

Two predators of *Dysdercus* spp. have been observed. *Phonoctomus fasciatus* P.B., fam. Reduviidae, imitating *Dysdercus superstitiosus*, and *Phonoctomus formosus* Dist., fam. Reduviidae, imitating *D. melanoderes*. Both these species of Reduviid prefer more shaded situations to those prevailing in the cotton fields. Occasionally nymphs of both species can be found on cotton but it is unlikely that they have bred in this situation.

It is not considered that it would be possible to aid the increase of either of these predators or the Tachinid parasite in order that they might become more efficient checks on the increase of the cotton stainers than they are at present.

BOLL WORMS.

Earias biplaga Walk., and E. insulana Boisd., spiny bollworms of cotton.

The adult moths of these two species are somewhat similar in appearance both being approximately half an inch in length. The female of *Earias biplaga* has fore-wings light-yellow to light-green in colour and bordered with brown on the distal margin, and a large irregular brown patch on the fore-wing. This patch is absent in the male. *Earias insulana* varies from brown-yellow to green and has no brown distal border. The female has no brown patch on the fore-wing. The hind-wings of both species are grey in colour. The larvae of both species differ slightly in coloration. Both are characterised by the fleshy spines on the body, hence the name of spiny boll-worm.

Pomeroy (2) has described the life-history in detail in Nigeria. The eggs hatch in three to six days, the average larval life being 13 days, with a maximum of 25 days and a minimum of 9. The longevity of the female was found to average 10 to 11 days. The total number of eggs laid by one female average 51.

Oviposition takes place at night and the eggs are laid singly on the bracts of buds and bolls. They are green to blue in colour and highly sculptured. Early in the season, before fruiting has commenced, the young larvae hatch out subsequently destroying the bud and opening flower. Later when fruiting is in full swing, damage is chiefly confined to young bolls, the young larvae boring into the pericarp and destroying one or more of the developing seeds. When the bolls are young this results in shedding. The larvae move on from boll to boll until full-grown. Pupation takes place inside the bracts, on the bolls, and on the stems. The pupa is enclosed in a tough fibrous boat-shaped cocoon. According to Pomeroy the pupal period varies according to temperature during the cotton season, the average time being from 11 to 12 days.

Alternative food-plants in Togoland are the fruits of *Hibiscus esculentus, Sida,* sp., *Urena lobata,* and *Abutilon* and the flowers of *Hibiscus sinensis. Earias biplaga* has also been bred from Cacao on which it attacks developing buds and newly unfurled leaves.

In Togoland and the Trans-Volta district no parasite of *Earias* spp. has been obtained. Pomeroy mentions two species of Braconid having been obtained in Nigeria. A Braconid has been obtained from *Earias biplaga* on cacao at Asamankese in the Colony

PLATE IV.

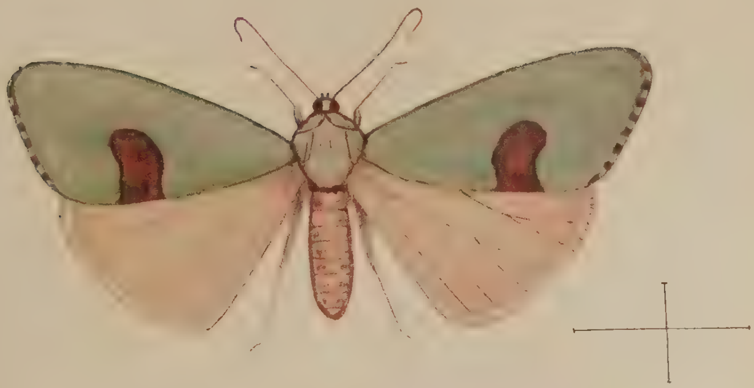


Fig. 1. Earias biplaga. Wlk. ♀

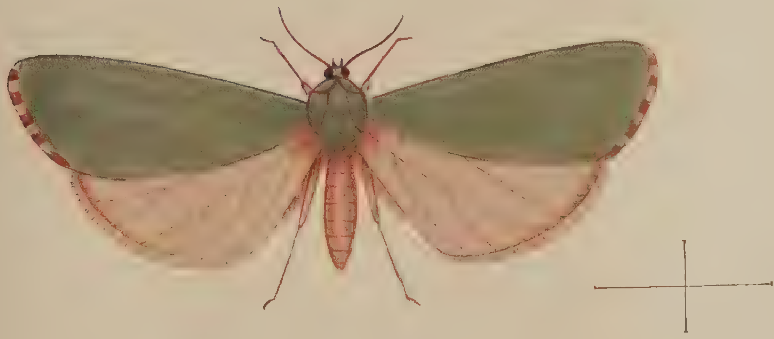


Fig. 2. Earias biplaga. Wlk. ♂

Fig. 3. Larva of Earias biplaga.
(after Pomeroy).

Argyroploce Leucotreta. Meyr.

The adult moth is small, about a third of an inch in length, with fore-wings and body dark brown with fuscous markings.

The newly hatched larva is yellow white in colour with a dark head and thoracic shield. Later the larva becomes rose-pink in colour. All stages are characterised by the dark thoracic plate. The larvæ have been mistaken for the Pink Boll Worm of Egypt, *Platyedra gossypiella,* but the latter has not yet been recorded from British West Africa.

Pomeroy (2) has also described the life-history of this moth in detail in Nigeria. The eggs are laid on the carpels of green or opened bolls, on the buds, and occasionally on the bracts. He states that they are usually laid singly but instances have been observed when two were laid partly overlapping one another. The larvae on hatching immediately seek a weak place in the carpel wall in order to enter the boll. According to Pomeroy buds are are also destroyed but this has not been observed in Togoland. The egg period is from 4 to 5 days. The larval stage was found to average fifteen and a half days. The full-grown larvae migrate from the boll on which they have been feeding and usually spin a narrow cocoon of tough white silk amongst the rubbish on the ground at the base of the plant. Pupation does not take place in the bolls. During the months from the beginning of September to the end of December the pupal period was from 12 to 14 days.

In the Trans-Volta District of the Colony and in Togoland only occasionally are the larvae of this moth found attacking green bolls, although they were exceedingly common in prematurely opened and aborted bolls. No parasites were obtained.

Diparopsis castanea Hampsn.

After considerable investigation this boll-worm which is common in other cotton growing countries, including Southern Nigeria, has not been observed to occur in the Trans-Volta District and Southern British Togoland. It occurs, however, in the Northern Territories of the Colony.

As it is a potential pest of cotton in this country details of its life-history and habits as obtained by Pomeroy (2) in Nigeria are recorded here.

The eggs are bright turquoise-blue, spherical in shape and flattened at the base and densely sculptured. Oviposition takes place at night and the eggs are deposited singly on the buds, bracts, and terminal shoots. The incubation period is from five to six days. The newly hatched larva is white with legs and head dark-brown to black. As the larva increases in size it becomes brick-red, and later pale bluish green with prominent rose-pink markings, the thoracic segments being suffused with pink. The young larva on hatching commences to bore into the nearest bud or boll. Young larvae often migrate from one boll to another, but after the third

moult usually confine their attention to one boll. For this reason the damage is less serious than that caused by *Earias* spp., Pomeroy found the larval stage before entering the soil to pupate to be from 18 to 24 days during January at Moor Plantation. The larvae crawl down or drop off the food plant and enter the soil to a depth of from four or five inches and construct a strong earthen cell in which they generally remain from 2 to 5 days before pupating. The majority of the adults emerge within 22 days but a certain proportion remain dormant for a very long period in the ground. It is assumed that this long pupal period is the most important factor in carrying this boll-worm on from season to season.

No other food plants than Cotton have been found.

OTHER PESTS OF COTTON.

Helopeltis Bergrothi Rent.

The adults and nymphs of this Capsid bug occasionally do considerable damage to cotton early in the season by sucking the growing shoots, stems, and leaves. Attack ceases as soon as the dry season sets in. Severely attacked plants become stunted and in less severe attacks bud production is retarded. Abscission of the leaves also occurs.

Lean (4) has worked up the life-history in detail in Nigeria. The writer has also studied the life-history of the same species on Cacao in the Gold Coast. According to Lean the eggs are embedded in the issues of the stem or leaf. The egg is elongate and banana-shaped. At the exposed end there are two long processes which project, one slightly longer than the other. The duration of the egg stage on cotton was found to be from 11 to 16 days with an average of 12 to 13 days. Lean records five instar periods. The total nymphal period was found to be from 17 to 21 days. In cotton growing areas of Southern British Togoland no other food-plants of *Helopeltis* have been observed. Golding (4), Nigeria, states that he has found adults on the Hogplum, *Spondias lutea.* In forest country it has a large range of food-plants.

Predators in Nigeria consist of *Reduviids, Mantids* etc. and the larva of a Syrphid fly, *Xanthogramma pfeifferi,* Bigot. which capture the nymphs at time of ecdysis. An internal Braconid parasite *Euphorus* (?) *nigricarpus,* Szép., has been bred out (by Lean) from nymphs of *Helopeltis.*

Aphis Gossypii.

Adults and nymphs of this Aphis infest the under side of the leaves, inside of the bracts of bolls and flower, and the carpels of developing bolls, and buds. The infestation reaches its maximum during and following periods of drought, owing to these periods being unfavourable to natural enemies.

Other food-plants are *Hibiscus* spp. and Cucurbits.

In French West Africa, Vayssière and Mimeur (5) state that apterous females are capable of living 25-30 days and produce young after one week. In October the life of the apterous female is longer and reproduction less. The dry season is passed in isolated groups.

During severe infestations abscission of the leaves takes place and attacked buds are shed.

Natural enemies are numerous. The larvae and adults of two Coccinellid beetles, *Chilomenes vicina* Meds., and *C. lunata* F., feed on the colonies. The larvae of the Syrphid fly, *Ischiodon scutellare* F., are also predaceous on the colonies. In Nigeria, Peacock (6) mentions that the Syrphids, *Paragus borbonicus,* Mcq., *Syrphus aegyptius,* Wied., and *S. nasuta,* Mcq., also prey on the colonies. In Togoland the larva of a species of Hemerobiid have also been observed preying on the colonies.

Syagrus Calcaratus.

The larvae of this Eumolpid beetle did considerable damage to the roots of exotic cottons at Kpedsu early in the 1926-27 season, and to a lesser extent to the roots of native cottons in the vicinity. Nothing is known of the life -history of these beetles but it was found that they are dependent on moist soil conditions for the completion of their life-history. On a two acre plot of native cotton in which the ground had a slight slope the higher ground was almost free from attack. An interesting feature of this latter infestation was its occurrence shortly after the termination of the dry season. On examination of the roots the majority of the larvae were found to be full grown. At Kpedsu there is apparently a layer of soil of higher moisture retaining capacity a few feet below the surface and it is possible that these larvae survived the dry season by burrowing down to this moister layer.

The adults were observed to live inside the bracts of buds and bolls and to eat the bracts and calyes. Golding (7) states that in Nigeria, from July to October, the adults were observed to feed openly on the leaves and petioles.

Other food-plants observed in Togoland are *Hibiscus* spp., *Urena lobata* and *Sida* sp.

Symptoms of attack are wilting of the leaves and subsequent abscission. Native cottons have a better power of recovery than exotic cotton and new leaves may be produced, whereas with exotic cottons occasionally a few new leaves may be produced but the plants usually die.

An examination of the soil and roots from 45 plants on a two acre plot of the " Sonko " variety of native cotton gave an average of six larvae per plant. These plants were taken from all parts of the plot and all showed severe damage to the root-system.

PLATE V

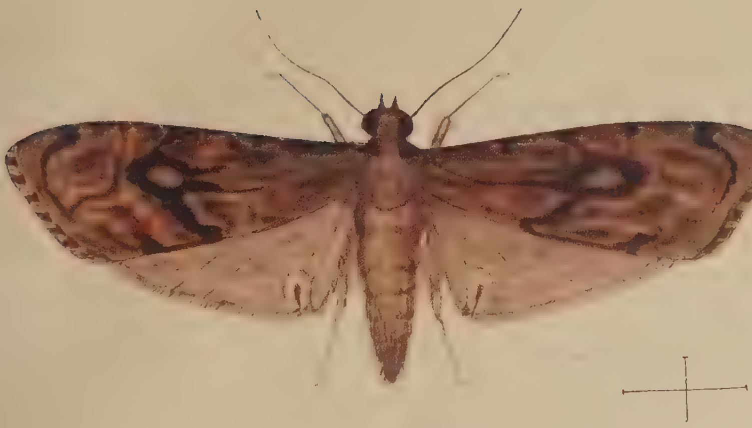


Fig. 1. Argyroploce leucotreta. Meyr.

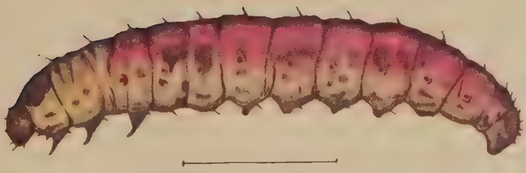


Fig. 2. Larva of A. leucotreta.
(after Pomeroy).

Fig. 3. Syagrus calcaratus. F.

Sylepta derogata. F., The Cotton Leaf Roller.

This Pyralid moth is not a serious pest of cotton in the areas investigated. Its life-history was not worked out. Eggs are laid on the under surface of the leaves and the young larvae on hatching feed on the lower epidermis. As they increase in size they roll up the leaf for protection fixing the edges with silk. Pupation takes place in this roll.

The larvae are heavily parasitised by a species of Chalcid. The parasitic larvae emerge in numbers from the host and spin small white cocoons in which they pupate attached to the hairs of the dead host.

The larvae are also parasitised by an undetermined species of Tachinid fly.

PART III.

ASSESSMENT OF DAMAGE CAUSED BY STAINERS AND BOLLWORMS.

An attempt has been made to estimate the amount of loss and damage caused by Stainers and Bollworms. This work was carried out at Kpedsu in the Adaklu division of British Togoland, at Ve-Deme and Ve-Höeme in the Ve division, and at Abor, north of the Keta lagoon in the Trans-Volta district of the Colony.

At Kpedsu and Abor three sample plots consisting of one sixteenth of an acre each were taken on each variety of cotton grown on the respective stations. On "Ishan", "Sonko", "Kadeanyigba", at Kpedsu, and "Sonko" and "Allen" at Abor. At Ve-Deme and Ve-Höeme one plot of "Ishan" was selected at the former place and one of the local "kidney" variety at the latter. Owing to the size of the plots it was found impossible to take three sixteenth-acre plots on each, therefore two only were selected. The plot at Ve-Höeme was an ordinary native-owned farm which had originally been planted up with food crops as well as cotton and therefore there were considerably less plants per acre than at the other places.

All records taken from these sixteenth-acre plots are the average of the two, or three sample plots, as the case may be.

Bud Shedding.

Extensive bud shedding takes place as a general rule at all places and on every variety of cotton, and is mostly physiological or caused pathologically through damage to the root system or stems.

In no case were Stainers observed sucking buds and it is therefore assumed that no bud shedding is caused by them. Bollworm attack on buds invariably results in shedding. However, during the season when these records were taken boll-worm injury, except at Abor, was not very great.

Sample bud sheds were collected from the sixteenth-acre plots and Table II gives the percentage of buds showing injury due to Bollworms at Kpedsu, Ve-Deme, Ve-Höeme and Abor on the different varieties from which records were taken, at monthly intervals.

No figures were obtained to ascertain the total bud shedding but the percentage is known to be large as the plants are incapable of carrying all buds that set. Therefore there is a large natural shedding. It may be assumed that bud shedding is compensatory, and that those buds that are injured are the first to be shed physiologically, being replaced by uninjured buds that would otherwise be shed. Therefore it may be assumed, ercept when shedding of bollworm-attacked buds is excessive, no damage is caused.

Boll Shedding.

Young newly formed bolls are invariably shed after being damaged by Stainers or Bollworms. Older bolls as a general rule remain on the plant except in a few cases when attacked by bollworm. Table III shows the percentage of shed bolls showing Stainer and Bollworm injury, from each variety from which records were taken, at Kpedsu, Ve-Deme, Ve-Höeme and Abor.

These figures were obtained by the collection of sample sheds from each of the sixteenth-acre plots and classified according to injury.

It was impossible to collect all the bolls that were shed. By counting the daily flower production on the sixteenth-acre plots and collecting all bolls that ripened or mummified on the plants without being shed, it was possible to calculate the shedding of each variety. This was done at Kpedsu, Ve-Höeme and Abor.

Table IV. illustrates the theoretical boll shedding during the whole period which records were taken and at approximately monthly intervals in that period.

It may be assumed that one puncture is a good as a number to cause shedding. This may be so, but by studying Table III, it will be seen that some of the plots showing the highest theoretical shedding averaged over 65 per cent shed bolls with no blemishes whatsoever. The majority of shed bolls consist of those that have just set and it is indicated that, with bolls as with flowers, shedding is selective and not dependent on the direct attack of insects on bolls. This point could be ascertained by taking the history of a large number of bolls on the plants from time of dropping of the flower to time of shedding or opening and recording date and nature of all external blemishes. It is understood that this work has been done in Nigeria with conclusions that shedding is not directly due to insect attack on bolls. This work has not yet been published.

Shedding appears to rise during periods of heavy flower production.

Damage to Bolls that are not shed.

Besides loss of crop due to shedding of buds and bolls and stained but otherwise healthy lint an enormous loss of crop occurs in some areas due to the total or partial abortion of bolls that remain on the plants. Bolls may mummify, or open prematurely, or one or more locks may be completely destroyed. It has been proved by Nowell (8) in the West Indies and by Laycock (9) in Nigeria that total or partial abortion is due to the action of Internal Boll Disease. It has also been proved that Internal Boll Disease cannot infect a boll unless the pericarp has been damaged in some way. It has been found that not only the injury caused by boll-worms and boll-eating beetles is capable of causing infection, but that the ordinary punctures through the pericarp made by Stainer nymphs and adults is sufficient. It is not yet known whether the spores of Internal Boll Disease are actually carried by Stainers.

During the period the writer was engaged on investigation of the damage caused by cotton pests, it was impossible to obtain information on the other pathological factors, other than insect, that cause damage to ripening bolls, no Mycologist being present. The most important of the other factors is probably abortion due to Anthracnose. The following data do not differentiate between mummification and abortion of bolls that may result from causes in which insects have no direct part in bringing about. All damaged bolls are considered as being the direct result of insect injury.

Table V gives the numbers and percentages of bolls picked that are damaged. In recording partially aborted bolls no record was made of the number of locks damaged. If an opened boll contained lint that was classified as damaged. Clean bolls only include those containing entirely clean lint the slightest amount of staining putting it in the partially aborted or stained grade.

From the above table it will be observed that although *Argyroploce leucotreta* does not reach a high percentage during the greater part of the season there appears to be a tendency for the percentage to rise at the end of the season. This is probably accounted for by the large percentage of aborted bolls that are left on the plants at the end of the season thus increasing the amount of breeding material available causing an increase of attack on green bolls.

From Table V it will be seen that on both plots at Ve there is a large increase in the number of clean bolls produced and a corresponding decrease in the number of aborted bolls. The reason for this is explained later on in this paper but by consulting the Stainer Index (Graphs 1 to 4) it will be seen that the Stainer population at Ve, particularly at the time of setting of the crop, was considerably lower than at Kpedsu or Abor.

Table VII. gives the percentage of stained to clean seed-cotton picked over three seasons at Kpedsu, and one season at Ve and Abor.

Why the amount of stained seed-cotton picked at Kpedsu should have risen towards the end of the season in the season 1923-24, is unknown but the rainfall during the dry season was considerably above the average. There is no record regarding the intensity or length of the harmattan during that season. During all other seasons, except at Ve, the amount of stained seed-cotton has decreased as the season advanced. The decrease at Kpedsu and Abor and increase at the end of the season at Ve, is explained in another part of this paper. It may be noted here, however, that at Kpedsu in the 1925-26 season the amount of stained was considerably less. This is due to the late ripening of the crop, the majority of the seed-cotton being reaped in February. The same applies to Ve in the last season, although here other factors come in as well.

Table VII shows that Kpedsu, with the exception of the season 1923-24, the percentage of stained seed-cotton picked during the months of December and January, is far higher than the percentage picked during February and March. By consulting the Stainer Index Graph for Kpedsu during the 1926-27 season it will be seen that the Stainer Index reaches its peak 3 weeks after the first flowering peak. This means that the developing bolls resulting from this flowering cycle are subject to the highest stainer attack. The developing bolls resulting from the second flowering cycle are not subject to any great stainer concentration.

The amount of stained seed-cotton at Ve-Deme and Ve-Höeme is probably more accurately estimated than that at Kpedsu or Abor.

TABLE II.—Bud Shedding Percentages.

Variety	KPEDSU. Ishan.			KPEDSU. Sonko.			VE. Kady.			VE. Kidney.			VE. Ishan.		
Month.	Tot. Shed.	B.W. attack.	% B.W.	Tot. Shed.	B.W. attack.	% B.W.	Tot. Shed.	B.W. attack.	% B.W.	Tot. Shed.	B.W. attack.	% B.W.	Tot. Shed.	B.W. attack.	% B.W.
November ..	249	9	3.6%	189	15	7.9%	343	84	24.5%	168	13	7.7%	29	6	20.7%
December ..	291	19	6.5%	506	38	7.5%	664	96	14.5%	254	9	3.5%	104	12	11.0%
January	229	31	13.5%	202	69	34.2%	329	77	23.4%	57	0	0.0%	63	6	9.5%
February.. ..	247	44	17.8%	62	17	27.4%	103	17	16.5%	4	0	0.0%	6	0	0.0%
March	178	20	11.2%	112	60	53.6%	64	17	26,6%	75	1	1.3%	40	0	0.0%
Total	1,192	123	10.3%	1,071	199	18.6%	1,503	291	19.3%	558	23	3.9%	242	24	9.9%

Variety.	Allen.			Sonko.		
Month.	Tot. Shed.	B.W. attack.	% B.W.	Tot. Shed.	B.W. attack.	% B.W.
November	363	224	61.7%	154	43	27.9%
December	864	394	45.6%	585	119	20.3%
January	151	27	17.9%	335	16	4.8%
February	110	14	12.7%	277	19	6.9%
March	126	13	10.3%	132	11	8.3%
Total	1,614	627	41.6%	1,483	208	14.0%

TABLE III.—BOLL SHEDDING AND INSECT ATTACK, Etc.

	KPEDSU.												VE.							
	"Ishan."				"Sonko."				"Kadeanyigba."				"Kidney."*				"Ishan."			
Month.	Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.	Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.	Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.	Shed Bolls collected.	% With Boll-worm Injury.	% With stainer Injury.	% Shed through other causes.	Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.
Nov. ..	2503	0.4%	31.0%	68.6%	1,671	0.4%	31.3%	68.3%	2713	4.9%	40.2%	54.9%	84	0%	* 38.1%	61.9%	432	1.4%	6.0%	92.6%
Dec. ..	897	0.4%	34.8%	64.8%	1,800	1,3%	31.5%	67.2%	2,710	4.2%	44.9%	50.9%	398	2.3%	27.4%	70.3%	1,251	0.4%	0.4%	93.2%
Jan. ..	1,154	0.6%	15.9%	83.5%	1,717	1.9%	18.7%	79.4%	1,944	6.6%	21.1%	72.3%	1,026	0.2%	7.9%	91.9%	1,155	0.0%	4.4%	95.6%
Feb. ..	1,915	0.7%	16.3%	83.0%	678	2.4%	14.0%	83.6%	1,402	2.5%	16.2%	81.3%	116	2.6%	9.5%	87.9%	115	3.5%	13.0%	83.5%
March.	311	3.5%	22.8%	73.7%	53	3.8%	32.1%	64.1%	239	12.1%	28.8%	59.1%	24	0%	1.7%	98.3%	132	2.3%	12.1%	85.6%

TABLE III.—BOLL SHEDDING AND INSECT ATTACK, Etc.—*continued.*

Month.	ABOR. "Allen." Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.	"Sonko." Shed Bolls collected.	% With Boll-worm Injury.	% With Stainer Injury.	% Shed through other causes.
Nov. ..	1,224	25.9%	25.3%	48.8%	546	1.5%	49.1%	49.4%
Dec. ..	2,049	22.2%	34.5%	43.3%	1,262	8.2%	53.1%	38.7%
Jan. ..	1,157	12.1%	47.2%	40.7%	822	5.2%	48.7%	46.1%
Feb. ..	384	15.1%	39.1%	45.8%	432	7.6%	45.6%	46.8%
March.	240	15.2%	59.6%	25.2%	148	14.9%	64.2%	20.9%

*High Stainer per cent due to proximity of abandoned previous season cotton. Pulled up at end of the month resulting in lower successive monthly percentages.

N.B.—In the above Table shed bolls showing both bollworm and stainer injury are classified under bollworm injury.

TABLE IV.—BOLL SHEDDING.

Place.	Plot.	Period.	% Theor. shed to possible boll production.	% Theor. shed to possible boll production for whole period.	%flower production to total flower production.
KPEDSU.	"Ishan"	Nov. 8th.– Dec. 11th.	22.48%		27.42%
		Dec. 11th.– Jan. 12th.	4.29%		13.56%
		Jan. 12th.– Feb. 12th.	17.46%		44.65%
		Feb. 12th.– Mar. 21st.	12.69%	56.92%	14.37%
	"Sonko"	Nov. 9th.– Dec. 15th.	21.22%		49.57%
		Dec. 15th.– Jan. 15th.	16.42%		33.33%
		Jan. 15th.– Feb. 16th.	11.04%		15.01%
		Feb. 16th.– Mar. 22nd.	4.36%	53.04%	2.09%
	"Kadean-yigba"	Nov. 8th.– Dec. 15th.	8.55%		30.03%
		Dec. 15th.– Jan. 15th.	11.95%		30.31%
		Jan. 15.– Feb. 16th.	5.56%		32.71%
		Feb. 16th.– Mar. 22nd.	2.08%	28.14%*	6.95%
VE.	"Kidney"	Nov. 2nd.– Dec. 8th.	4.96%		28.93%
		Dec. 8th.– Jan. 13th.	20.85%		53.95%
		Jan. 13th.– Feb. 12th.	8.08%		8.83%
		Feb. 12th.– April 3rd.	1.41%	35.30%	8.29%

*Possibly too low owing to errors in flower counts.

TABLE IV.—BOLL SHEDDING—*continued.*

Place.	Plot.	Period.	% Theor. shed to possible boll production.	% Theor. shed to possible boll production for whole period.	% flower production to total flower production.
		Nov. 27th.–Dec. 11th.	3.38%		31.76%
	"Ishan"	Dec. 11th.–Jan. 13th.	14.64%		35.12%
VE.		Jan. 11th.–Feb. 5th.	0.47%		4.90%
		Feb. 5th.–April 5th.	22.16%	40.65%	28.22%
		Nov. 20th.–Dec. 20th.	41.35%		45.75%
	"Allen"	Dec. 20th.–Jan. 21st.	21.85%		35.91%
		Jan. 21st.–Feb. 21st	13.79%		9.67%
		Feb. 21st.–Mar. 21st.	7.56%	84.55%	8.67%
		Nov. 20th.–Dec. 20th.	35.96%		48.42%
ABOR.	"Sonko"	Dec. 20th.–Jan. 21st.	29.72%		38.16%
		Jan. 21st.–Feb. 21st.	7.62%		11.59%
		Feb. 21st.–Mar. 21st.	5.94%	79.24%	1.83%

Although by no means conclusive it will be seen by comparing this table with Graphs 1–4 for the same plots, that there is no relation between stainer population and the amount of shed bolls. There is, however, a definite relation between theoretical shedding and flower production,

TABLE V.—CLASSIFICATION OF OPENED OR MUMMIFIED BOLLS ACCORDING TO INJURY.

Place.	Variety.	Bolls picked.	Totally Aborted Bolls.	% Totally Aborted.	Partially Aborted or Stained Bolls.	% Partially Aborted or Stained.	Clean Bolls.	% Clean.	% Total Bolls picked showing bollworm injury.
Kpedsu ..	" Ishan "	4,549	1,955	42.97%	2,418	53.15%	176	3.88%	3.76%
" ..	" Sonko "	4,369	1,593	36.45%	2,596	59.40%	180	4.15%	4.39%
" ..	" Kadean-yigba "	11,33	2,941	25.91%	7,783	68.69%	606	5.40%	4.68%
Ve-Höeme	" Kidney "	4,4100	599	13.58%	1581	35.85%	2230	50.57%	1.00%
Ve-Deme	" Ishan "	9,067	816	9.00%	3,284	36.22%	4967	54.78%	0.96%
Abor ..	" Allen "	3,406	1,101	32.32%	2,187	64.21%	118	3.47%	1431.%
" ..	" Sonko "	3,232	567	17.50%	2,484	76.88%	180	5.58%	1077.%

Note.—High bollworm damage on "Sonko" variety at Abor is due to spread from the adjacent Allen plot.

Earias biplaga and *E. insulana* were almost entirely responsible for all bollworm injury. Table VI gives the percentage occurrence of the various species of bollworm at Kpedsu and Abor from attacked bolls collected from the plants.

TABLE VI.—PERCENTAGE OCCURRENCE OF THE VARIOUS SPECIES OF BOLLWORM

Date.	Variety.	No. of attacked bolls collected.	% Containing Larvae.	*Earias biplaga.*	% *E. biplaga.*	*A. leucotreta.*	% *leucotreta.*	*D. castanea.*	% *D. castanea.*	*P. litura.*	% *P. litura.*
Dec. 12th	" Kady " Kpedsu ..	29	41.4%	11	91.7%	1	8.3%	0	0.0%	0	0.0%
Dec. 8th	" Kady " Kpedsu ..	—	—	21	87.5%	3	12.5%	0	0.0%	0	0.0%
Feb. 28th	" Hybrids " Kpedsu ..	235	29.8%	65	22.9%	5	7.14%	0	0.0%	0	0.0%
Dec. 21st	" Allen " Abor ..	231	22.9%	49	92.5%	4	7.5%	0	0.0%	0	0.0%
Feb. 3rd	" Allen " Abor ..	411	19.2%	59	74.7%	20	25.3%	0	0.0%	0	0.0%
Feb. 3rd	" Sonko " Abor ..	63	25.4%	4	25.0%	12	75.0%	0	0.0%	0	0.0%

TABLE VII.—PERCENTAGES OF STAINED TO TOTAL COTTON SEED PICKED.—SEASON 1926–27.

Place.	Variety.	October.		November.		December.		January.		February.		March.		Total yield per acre.	% Stained.
		Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.		
Kpedsu	"Ishan" ..	—	—	—	—	lbs. 7¾	63%	lbs. 32½	51%	lbs. 16½	44%	lbs. 109	25%	lbs. 165¾	33.5%
	"Sonko" ..	—	—	—	—	35½	65%	59	57%	68	33%	28	20%	190½	44.8%
	"Kadeanyigba"	—	—	—	—	37¼	59%	25⅓	61%	156	26%	81¼	24%	300	32.1%
Ve	"Kidney" ..	—	—	—	—	—	—	22	32%	202	21%	46	35%	370	26.4%
	"Ishan" ..	—	—	—	—	—	—	250	29%	436	20%	126	24%	812	23.7%
Abor	"Allen" ..	lbs. 50	33%	lbs. 32½	62%	20¾	43%	25¼	28%	83½	4%	—	—	—	—
	"Sonko" ..	—	—	6½	62%	16¾	49%	35	17%	130	3%	—	—	—	—

TABLE VII.—PERCENTAGES OF STAINED TO TOTAL COTTON SEED PICKED.—SEASON 1925–26.

Place.	Variety.	October.		November.		December.		January.		February.		March.		Total yield per acre.	% Stained.
		Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.	Monthly yield per acre.	% Stained.		
Kpedsu	"Sonko" ..	—	—	—	—	—	—	lbs. 36	28%	lbs. 137	12%	lbs. 67½	7%	lbs. 240½	12.9%
	"Kadeanyigba"	—	—	—	—	—	—	34½	32%	206	14%	36½	18%	277¾	16.9%
SEASON 1924–25.															
Kpedsu	"Sonko" ..	—	—	—	—	lbs. 1½	67%	lbs. 24½	53%	lbs. 41	20%	lbs. 62½	17%	lbs. 129½	25.1%
	"Kadeanyigba"	—	—	—	—	8	50%	39¼	41%	53¼	30%	81¼	20%	181¼	29%
SEASON 1923–24.															
Kpedsu	"Sonko" ..	—	—	—	—	lb. 1	50%	lbs. 33	33%	lbs. 64¾	35%	lbs. 43	62%	lbs. 141¾	42.7%
	"Sonko" ..	—	—	—	—	—	—	17¼	23%	68½	32%	57¼	60%	144	41.5%

PART IV

INCIDENCE OF STAINERS ON COTTON, AND OTHER MALVACEAE.

Besides the various species of *Gossypium* there are a large number of other Malvaceous shrubs and trees that are alternative breeding plants of the cotton stainer. These are the seed capsules of *Hibiscus* spp., the most important being *Hibiscus esculentus;* seeds of *Adansonia digitata;* the seeds of the silk cotton, *Eriodendron anfractuosum* and *Bombax* spp ; *Thespesia* sp. ; the seed-capsules and of the wild shrubs, *Urena lobata, Sida* sp., and *Abutilon* sp. The adults and nymphs have also been observed feeding on the seeds of *Sterculia* spp. and on ripening Guinea Corn.

The occurrence of *Adansonia, Eriodendron* and *Bombax* has already been stated early in this paper. Near the coast *Hibiscus esculentus* is grown in quantities, commonly in pure stands. Further north, in the Adaklu and Ve districts, the seeds are scattered in small quantities amongst other food crops. It is planted in March or April and near the coast again in September. It ripens in May and June, the seed capsules becoming favourable as food for the cotton stainer in April and May. The second crop ripens in November and December, becoming favourable to the stainer in October and November. On the banks and on some of the islands in the river Volta, particularly at Adidome, advantage is taken of alluvial soil when the river is at its lowest and a third crop is planted in January ripening in March and April. The seed capsules become favourable a month or so before they are harvested At harvesting time the seeds are too hard for food.

Adansonia commences to flower, in Southern British Togoland, in March reaching a peak in May and June. Fruiting commences in October and the fruiting period is an extended one. The fruits remain on the trees as late as July. They are not fed on by the Stainer until they fall and the pericarp breaks, open or rots exposing the seeds. When this happens Stainers are attracted in enormous numbers and breeding readily occur, oviposition taking place in the soil and debris around the fallen fruits. As soon as the seeds harden feeding and breeding ceases and the adults and the older nymphs migrate elsewhere.

Eriodendron commences to fruit as a general rule about the last week in December and continues to fruit up to end of March, although the majority of trees have fruited long before this date. In other parts of the Gold Coast Colony, particularly in forest regions, fruiting may occur later, but these are not cotton growing areas.

Bombax flowers about the same time as *Eriodendron* commences to fruit, and fruits from February to as late as the end of June.

The seed pods are not fed upon on the trees even after they have burst open, but only when the kapok and seed has fallen to the ground. When this occurs adult stainers are attracted in immense numbers and breeding commences on a large scale. The seeds soon dry up and the adults and nymphs migrate to the nearest cotton or to another tree that has commenced to fruit, meanwhile the younger nymphs become cannibalistic, feeding on each other and on other insect life in the vicinity. A common sight when the seeds have become dry is to see one or more adults or nymphs walking about with a seed impaled on the rostrum, the seed having dried in this situation.

Urena, Sida, and *Abutilon* and also *Sterculia,* fruit during the dry season at the same time as cotton. Nothing is known whether fruiting occurs again at some other period of the year.

As cotton is, or should be, cultivated as an annual, naturally the obvious method of pest control is the destruction of cotton plants at the end of the season and the removal or control of the various food plants in the vicinity. Unfortunately the latter method is not practical in this country. As it is, a large amount of cotton is left standing at the end of the season, although as a general rule it is abandoned, no cotton being collected from it the following season. With cotton left in this way, flowering and bolling occurs right through the non-cotton season. Cotton therefore left to grow as a perennial is as important a factor in carrying the cotton stainer over from season to season as other alternative food plants. The importance of the various alternative breeding plants of cotton stainers depends on the time at which they fruit, anything which has its fruiting period between two cotton seasons being important, and conversey, anything which has its only fruiting season at the same time as cotton being of little importance. Thus plants such as *Sterculia, Urena*, *Sida* and *Abutilon* are of little importance unless they have an additional fruiting period, or the fruiting period is prolonged long after that of cotton. In the case of *Eriodendron* and *Bombax*, in the cotton areas of Southern Togoland and the Trans-Volta district, the former has little bearing on carrying over the stainer from season to season, its only importance being that it enables the cotton stainer to carry over the dry season as it occurs in situations which are more humid than on the cotton field and also more shaded. The result is that, where cotton stainers are abundant, they are able to finish up the season on cotton in considerable numbers and there is, therefore, more chance of a larger number of individuals surviving the period between two seasons. *Bombax* is even more important in this way as it fruits later and its fruiting season is prolonged after that of cotton. However at Ve-Deme,

where the cotton stainer is not a serious pest, *Eriodendron* and *Bombax*, particularly the latter are common. Yet the cotton stainer commences each season in very small numbers. The stainer population on cotton does increase, however, at the end of the season.

Table VIII illustrates the periods when the more important breeding plants of *Dysdercus* are available. It will be seen that in districts where all these food-plants occur, that, even if cotton is destroyed at the end of the cotton season, the only period when no food is available is during August and September. Stainers would easily survive this period in sufficient numbers until the next Okro crop.

At Ve, *Adansonia* is uncommon and Okro is not an important factor owing to the small amount that is grown.

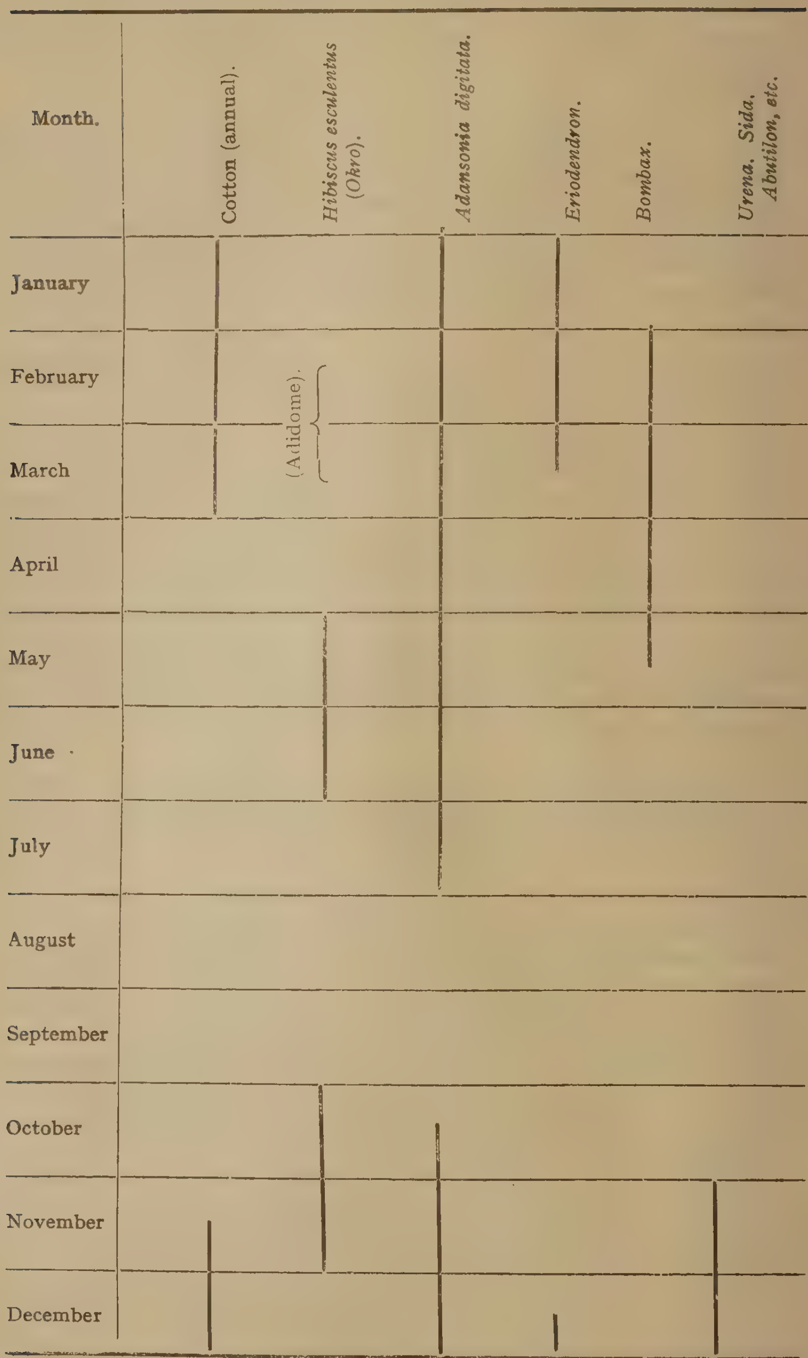
Migration of Adults to Cotton.

In the Adaklu division there is a migration of adult stainers to cotton early in the season (Graph 1.) The same no doubt occurs at Abor but records were instituted too late to obtain definite information on this point. From observations covering two cotton seasons this migration has been observed to occur soon after cotton commences to flower and some time before any bolls have commenced to mature. The same has been observed in Southern Nigeria (3) over a number of years. In the Ve division there is no migration (see Graphs 2 and 3.).

The migratory form of *Dysdercus* differs from the non-migratory form, the former being characterised by one small black spot on each hemelytron and the latter by a broad black band extending across the two hemelytra.

The occurrence of the adults and nymphs of *Dysdercus* spp. on cotton throughout the 1926-27 season is shown in Graphs 1-4. These figures were obtained by instituting the same method of obtaining the stainer gauge as used by Golding (10) in Southern Nigeria. On each plot and in each district in which records were taken, three one-eighth acre plots were marked out. Once a week these three plots were denuded of their stainer population by a standard number of pickers at the same time of day. The adults and nymphs from each one-eighth acre plot were then counted and the average of the three taken. This figure represents the degree of re-population on an eighth acre at weekly intervals on such and such a variety of cotton in such and such a district at different periods of the cotton season. The object of taking three plots and taking the average is to obtain a figure representative of the whole plot as it is known that the stainer population varies considerably in different parts of the same plot. Invariably one eighth acre plot always had more, or less, stainers collected from it than the others.

TABLE VIII.—PERIODS FOOD PLANTS AVAILABLE.



As contiguous plots of cotton naturally have a bearing on the stainer population of each other, depending on which happens to be at the most attractive stage, the records from all the plots at Kpedsu and Abor on which the index was taken are added together and the average per plot taken. This was not necessary at Ve as the two plots were separated by at least three miles.

Length of Adult Flight.

An attempt was made to discover the length of flight of the migratory form. When migration was at its height 500 to 1,000 adults were collected and marked with a small spot of paint. These marked adults were released at distances of three-quarters of a mile and one mile from the plantation at Kpedsu. From one batch of 800 released one mile north of the plantation three captures were made at subsequent index pickings on the plantation, the first, fourteen days after release. It was discovered that marked adults from this release were resting and feeding on a small stand of native-owned cotton one quarter of a mile from the place of release. It could not therefore be said that a flight of one mile was possible as the flight was obviously being made in jumps from food plant to food plant. Another release at a distance of one mile in a westerly direction, in which it was ascertained as far as possible befor-hand that there were no alternative food plants in a condition favourable as food in the line of flight, no captures were made. Since writing this it is understood that at Moor plantation in Nigeria captures have been made after a flight of one mile within twenty-four hours of release.

It is possible that migration is directional depending on prevailing wind. As a result of trap experiments put in hand two cotton seasons ago more adults were captured on traps north and north-east of the plantation, than south.

The Dry Season and the Cotton Stainer.

From the graphs indicating stainer occurrence during the cotton season it will be seen that as soon as the dry season commences the breeding ceases on cotton, and does not commence again until the end of the dry season when adults are migrating back from silk cotton.

This decrease was not so marked at Ve-Deme owing to this plot being situated on the fringe of transition forest where the same degree of aridity as in open country would not occur.

It will be noticed from Graph 4 that at Ve-Höeme there was a proportionately higher nymphal index at the beginning of the season as compared with that at Ve-Deme. The reason for this is that it was discovered some time after records had commenced that there was an old cotton farm near by which had been left over from the previous season, the land having been allowed to revert to bush.

Artificial Control Measures.

It has been found that, even if an effective artificial control measure for *Dysdercus* spp. could be obtained, that it would be impracticable to put it into operation at the present time or probably for years to come.

It was ascertained that a certain amount of control could be obtained by hand-picking, particularly if this is done at the beginning of the season when adult migration is at its height.

TABLE IX.—TRAP RECORDS.

Type of Trap.	Nos. of Stainers captured daily during week preceding dates below.										
	No. of Traps.	Dec. 15th		Dec. 24th		Jan. 8th		Jan. 17th		Jan. 31st	
		A.	N.	A.	N.	A.	N.	A.	N.	A.	N.
Crushed Cotton Seed	3	52	158	43	45	12	14	16	47	6	42
Crushed Baobab Seed (unshaded)	3	550	495	441	424	85	146	32	58	13	148
Crushed Baobab Seed (shaded) ..	3	—	—	—	—	394	1,232	97	397	14	159

Note.—A = Adults. N = Nymphs.

Experiments were put in hand to ascertain the comparative usefulness of various traps. For this purpose traps were constructed of fresh cotton seed, crushed cotton seed, *Adansonia* seed and crushed *Adansonia* seed, shaded and unshaded. Table IX shows the numbers of adults and nymphs caught at different times during the season on the various types of traps. It will be observed that shaded crushed *Adansonia* seed traps were the most effective. The evening was found to be the best time for collecting. Shaded crushed *Adansonia* seed traps were put out on the index plots on the plot that was at that time collecting the most stainers but no appreciable drop occurred at subsequent index pickings.

Traps consisting of crushed *Adansonia* seed put down at the beginning of the season would no doubt be effective in capturing migrating adults. However at that time *Adansonia* fruits are scarce and they would have to be stored from the previous fruiting season.

Cultural Control Measures.

By studying the stainer index and flowering and fruiting curves, illustrated in Graphs 1 to 4, it will be observed that the stainer index was exceedingly low at Ve-Deme and Ve-Höeme compared with that at Kpedsu, and that at the former places flowering and

fruiting occurred considerably later. It will also be seen that, whereas at Kpedsu and Abor there are two definite flowering and fruiting cycles, in the Ve District there is only one and that very definitely pronounced. The fruiting season at Ve is therefore considerably shorter. It has been ascertained that the average time of development from flower to opening of the boll at Kpedsu was 6 weeks, and at Ve, 8 weeks. The longer period of development at Ve retards the fruiting season still further. Whereas picking commenced in the third week in December at Kpedsu reaching its first peak between December 23rd and 30th, in the Ve district picking commenced in the second week of January reaching a prolonged peak from January 25th to February 15th.

Mason and Wright (11) working in Nigeria, found that at Oyo, situated in bush-savannah country boll shedding of native cotton was heavy in the early part of the flowering period. They remarked that " there would seem to be a tendency for Native cotton to delay setting its crop until the termination of the rains. It may be that this is one reason why it is generally less affected by the Internal Boll Disease, for the cotton stainer population apparently diminishes after the onset of the dry weather ".

The late setting of fruit and the consequent late fruiting season have an important bearing on the amount of cotton destroyed or damaged as a result of stainer attack. During the season 1926-27 the dry season commenced about December 23rd after which breeding gradually ceased on cotton and did not commence again until March. It will be observed that at Kpedsu the percentage of stained lint, and also of aborted and of partially aborted and stained bolls from ripe bolls resulting from the second flowering cycle, was much lower than that resulting from the first flowering cycle. This is due to the fact that at Kpedsu at the time of setting of bolls of the first fruiting cycle the stainer index was at its highest, where at the time of boll setting of the second fruiting cycle the stainer index was comparatively low owing to conditions being too arid in the cotton field for the stainer to breed. Also there was a more favourable food plant for it in the nature of fruiting silk-cotton trees. At Ve on the other hand during the setting of the only fruiting cycle the amount of stainers present was almost negligible. If fruiting had occurred earlier there would no doubt have been a migration of adult stainers to cotton resulting in a high percentage loss of crop. It will be seen that stainers were present in comparatively large numbers at Ve when there was food available. This was the case when the large number of silk-cottons in the neighbourhood, both *Eriodendron* and *Bombax,* were fruiting. At no time during the fruiting of cotton at Ve was cotton favourable to the stainer owing to conditions in the cotton fields being too arid.

An obvious control measure for the cotton stainer is therefore, the planting of cotton in areas where fruiting occurs late, or the planting or production of a variety by selection, which will naturally fruit late and has a short fruiting season. In connection with the

small stainer population on cotton at Ve during the period of setting of the fruit, it is of interest to note that on plants left over from the previous crop and those grown as perennials flowering and fruiting occurs considerably earlier, resulting in a higher stainer population at the beginning of the season, and consequent higher amount of stained lint. Newly planted cotton adjacent to cotton grown in this way is also more heavily stained owing to spread of individuals on to this cotton as the fruit begins to set.

This was very marked in the Ve, Kpandu and Hohöe districts where the growing of the same stand of cotton for two successive seasons had been recommended by the Germans.

It is understood that in Nigeria a variety of "Ishan" cotton has been selected that flowers and fruits late, and if grown by itself and not with contiguous plots of early flowering varieties, is not attractive to *Dysdercus* spp. until late in the season after the main crop has been harvested.

A disadvantage of growing native varieties of cotton is that these varieties will behave as perennials if allowed to do so. It is now almost impossible, and may be for years to come, to make the cotton farmer destroy his cotton plants at the end of the season. Exotic cottons on the other hand, have a tendency to behave as annuals and the growing of these would naturally facilitate the enforcement of a close season.

Unfortunately, however, in the cotton growing areas of Togoland and the Colony these cottons are more susceptible to the attacks of insects, particularly stainers and boll worms, and fruit earlier than the local native varieties.

In the Northern Territories of the Colony the dry season starts much earlier than in the south and is much more marked. Both native and exotic cottons commence to fruit after the dry season has commenced and when conditions are too arid for the cotton stainer to breed. Therefore here it should be possible to grow exotic cottons with a yield that should compare favourably with that of native cottons. In the Ve, Kpandu and Hohöe divisions of Southern Togoland, where all native cottons fruit late, experiments are being put in hand next cotton season in the growing of exotic cottons to see whether fruiting will occur sufficiently late to avoid the first migration of adult cotton stainers at the beginning of the season. It may be possible, owing to the absence of the more important alternative food-plants and the different climatic conditions than those further south, to grow an exotic cotton with a more valuable lint than the local native varieties without it being attacked to the same extent by *Dysdercus* spp. although it is possible that it will be attacked to a greater extent by bollworms.

The planting of varieties in contiguous plots and planting of the same varieties at different dates is unsatisfactory from the point of view of comparing yields or resistance to stainer attack. Stainers that are originally attracted to the earlier planted varieties migrate as

nymphs and adults in immense numbers to the later planted varieties as soon as the latter become attractive. This is very marked when growing two contiguous varieties, the one an earlier fruiting variety than the other. " Allen " cotton flowers and fruits considerably earlier than the local varieties of cotton, and whereas a local variety which in the ordinary way flowers and fruits too late to be attractive to adult stainers resulting in non-migration, may be growing contiguous to a plot of " Allen " cotton, the earlier fruiting " Allen " has already attracted adults which have commenced to breed in immense numbers before the dry season sets in. This results in the adults and nymphs migrating to the native cotton much earlier than would ordinarily be the case.

It appears to be impossible to cultivate an exotic cotton in Southern British Togoland and in the Trans-Volta District of the Colony, with the possible exceptions of Ve, Hohöe and Kpandu, without the cotton stainer becoming a serious pest. The same does not apply to the Northern Territories of the Colony owing to the more marked and earlier commencement of the dry season. Therefore, if it is intended to grow cotton on a commercial scale in the south and to eliminate as far as possible the cotton stainer as a pest, it will be necessary to produce by plant selection a local variety that will fruit late. This apparently has been done in Nigeria. Also, owing to the present poor commercial value of the present native cottons, it will be necessary to produce a variety with better quality lint. A step has been made in this way with the present " Ishan " variety of cotton which has been imported from Nigeria and which was improved in that country.

In districts where *Adansonia* is common it is unlikely that the stainer can be eliminated as a pest irrespective of the time of flowering and fruiting of cotton. Where practical, therefore, these trees should be destroyed.

SUMMARY.

1. The experimental work outlined in this paper was carried out at (i) Abor, in the Trans-Volta district of the Colony; (ii) at Kpedsu, representing the southern plains of British Togoland; and (iii) at Ve, representing the cotton growing areas north of the Togoland range.

2. It has been found that the harvesting season of cotton at Ve is later and shorter than either at Kpedsu or Abor. This is thought to be due to the heavier and more evenly distributed rainfall north than south of the Togoland range, and the greater degree of aridity during the dry season.

3. As a result cotton stainers are not a serious pest in the area comprising the Ve, Kpandu and Hohöe divisions of Togoland.

4. The absence of stainers as pests is also partly due to the scarcity of alternative breeding plants of the stainer, the chief of these being the Baobab, *Adansonia digitata*.

5. The insects attacking cotton are listed and their life-histories and habits detailed. The chief pests are the cotton stainer, *Dysdercus superstitiosus*, and the bollworms, *Earias biplaga* and *E. insulana*. The larvae of a beetle, *Syagrus calcaratus*, were reported for the first time as attacking cotton in Togoland. Serious damage was done to the roots of exotic cottons, and, to a lesser extent, to native cottons at Kpedsu.

6. It is assumed that no loss of crop occurs following insect attack to buds unless a very high percentage are injured, as extensive bud shedding takes place naturally, following physiological causes or damage to the plant body, this being of a selective nature.

7. It is indicated that no loss of crop results from shedding of bolls following insect injury, as shedding of young bolls is also selective, a large number of young bolls being shed naturally.

8. Abortion of one or more locks and staining of lint is the result of infection by Internal Boll Disease which gains ingress to the bolls through stainer punctures.

9. At Kpedsu and Abor only from 4% to 6% of the bolls which opened during the 1926-27 cotton season were entirely clean, whereas at Ve, 50% to 55% were clean. At Kpedsu 26% to 43% of the bolls were totally aborted, representing an entire loss of crop, and only from 9% to 14% at Ve. This higher percentage of aborted bolls at Kpedsu is due to the high stainer population at the time of the setting of the crop.

10. From the total number of bolls picked 11% to 14% of those at Abor showed bollworm injury, 4% to 5% at Kpedsu, and only 1% at Ve. The high percentage at Abor is due to the high susceptibility of "Allen" cotton.

11. The seed of the Baobab, *Adansonia digitata*, is the most important alternative breeding plant of the stainer owing to the prolonged fruiting period and the length of time the fruits remain on the trees.

12. Other alternative breeding plants are the seeds of *Eriodendron* and *Bombax*, and the seed capsules of *Hibiscus esculentus*.

13. Cotton plants that are not destroyed at the end of the cotton season are also important in carrying the stainer over from season to season, bolls being available on a small scale throughout the non-cotton season. They also commence to flower and fruit in quantity earlier the following season than newly planted cotton resulting in an early attraction of adult stainers and consequent earlier spread to annual cotton in the vicinity.

14. South of the Togoland range there is a migration of stainers to cotton. This migration corresponds with the first flowering peak of cotton. At Ve there is no migration.

15. Breeding of stainers on cotton ceases after the commencement of the dry season, owing to the aridity of the cotton fields, and does not commence again until late in the season.

16. The non-migration at Ve is assumed to be due to the late flowering of cotton in this district, and fruiting commencing after the dry season has set in. For this reason the stainer population throughout the season is considerably less than at Kpedsu, resulting in less abortion and staining.

17. It has been found that little success is likely to result in this country from the use of traps for stainers.

18. Control measures for the cotton stainer consist of the production of strains of late fruiting cottons from the present native varieties for planting in those areas where the cotton stainer is a pest, *i.e.* south of the Togoland range, and the destruction of Baobab trees where practicable.

19. The destruction of cotton at the end of the season.

20. The planting of early fruiting and susceptible varieties such as " Allen " cotton adjacent to late fruiting varieties will result in an early attraction of stainers to the former with a spread to the latter which would not otherwise occur.

21. Those areas in which the present varieties of native cotton naturally fruit late should be developed. These areas consist of the Ve, Kpandu and Hohöe divisions of British Togoland, and probably also the Vakpo and Aveme divisions.

22. There is at present no practical remedy for bollworm control.

24. Owing to the susceptibility of exotic cottons to stainers and bollworms these cottons should not be planted in the south.

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GRAPH I.

KPEDSU.

Reproduced at Survey H.Q. Accra, 1927.

GRAPH 2.

VE-DEME.

Reproduced at Survey H. Q. Accra, 1927.

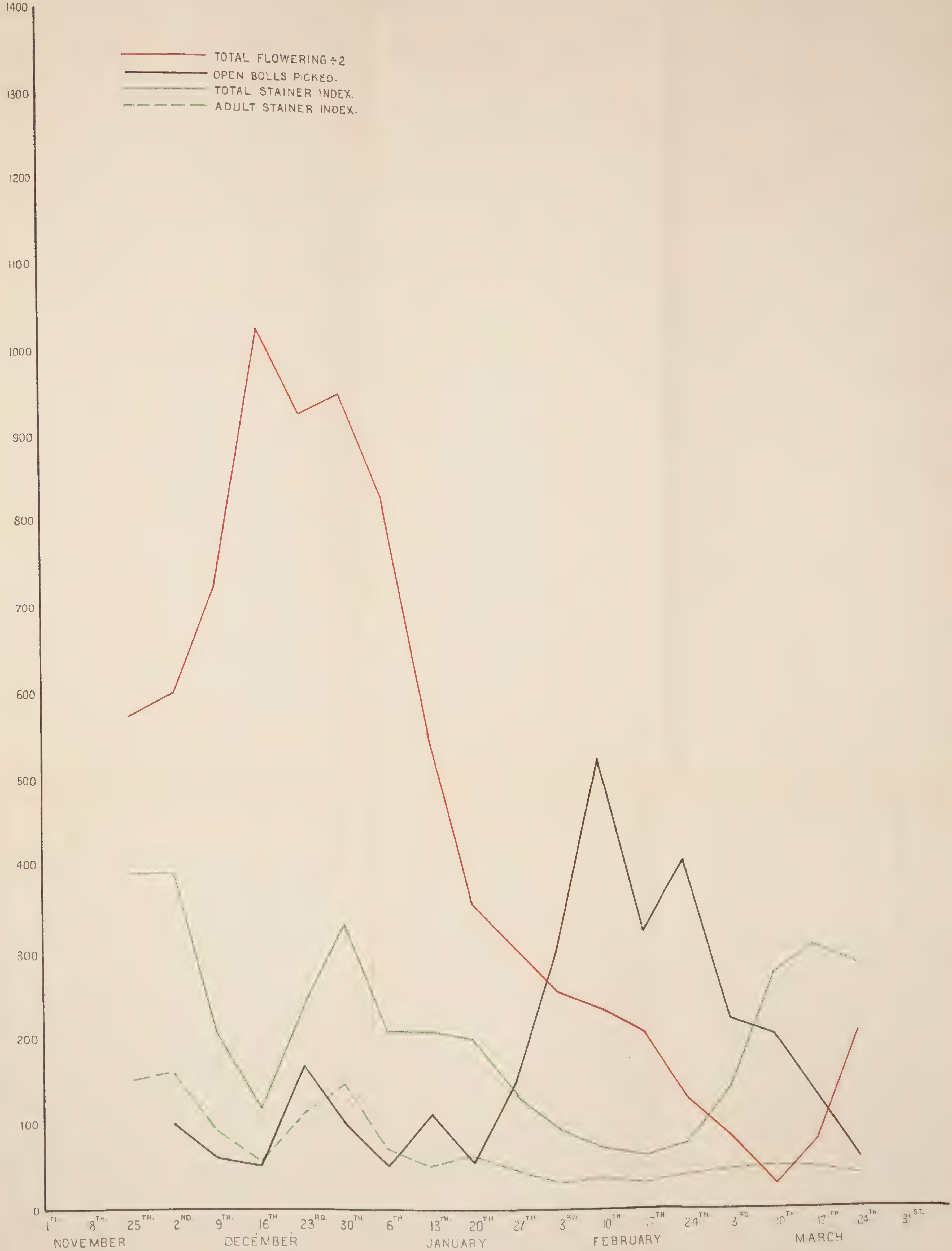
GRAPH 3.

VE-HOEME.

Reproduced at Survey H.Q. Accra, 1927.

GRAPH 4.

ABOR.



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BULLETIN No. 13.

Department of Agriculture,
Gold Coast.

YEAR-BOOK
1927.

Issued by
The Honourable the Director of Agriculture.

DEPARTMENT OF AGRICULTURE, GOLD COAST.

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[SEE OVER,

Chemical Division.

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Apprentice	Vacant.

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Apprentice	J. Cofie.

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Asst. Officer-in-Charge, Sisal Plantation	J. M. Wingate.
Officer-in-Charge, Coconut Plantation, Atwabo	W. C. Fishlock.
Instructor, Coconut Plantation, Atwabo	P. A. Herft.
Officer-in-Charge, Rice Factory, Essiama	F. A. Robb, B.Sc. (Edin.), N.D.A.
Asst. Superintendent, Cotton Development, Northern Territories ...	J. T. H. Stein, B.Sc. (Edin.).

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Assistant for Meteorology	J. M. Adams.

Training Centre, Kumasi.

Superintendent	T. Hunter.
Assistant Superintendent	W. T. O. Maidment, B.A. (Cantab.).

CONTENTS.

PAPER No. 1.

DEPARTMENT OF AGRICULTURE AND AGRICULTURAL INDUSTRIES, 1927.

By Hon. C. H. KNOWLES,
Director of Agriculture.

Cacao.

During the year just completed the amount of cacao exported has shown a fall, thus breaking the series of record crops which had succeeded one another for some years. This, however, must not be taken to indicate any serious set-back to the industry.

The crop of individual trees varies very much year by year, but this individual variation is practically obliterated by considering crops over a large enough area, since the variations year by year are due more to those local fluctuations in climatic conditions which are the basis of variations of agricultural crops in all countries. A paper in the Yearbook indicates some correlation between rainfall and crop, and this is an investigation which is being continued.

Another factor which is of great importance in this country is that the crop figures are the exports from the country. Taken over a few years they are reliable as a measure of the crops, but in comparing one year with another, they are liable to be misleading, being affected by such artificial factors as the withholding of the produce from the market by the grower or the exporter, and the shortage of transport facilities by land or sea.

The drop in the crop compared with last year is some 10 per cent., which, even if due to purely natural causes, cannot be taken to be in any way excessive.

Prices during the year have been very good.

Sanitation.

The work under the Cacao Sanitation Scheme was reorganised during the year, whereby the Department's first duty is confined to giving demonstrations of efficient methods in each village or other suitable centre, after which the farmers are required to apply the methods to their farms should the diseases requiring such treatment be present. The cultural side of cacao farming is being emphasised by the Inspectors, who also include references to the necessity for proper fermentation of the produce and complete drying.

In the event of the advice not being taken, the duty of clearing away diseased material then falls on the Government.

Manurial Experiments.

The manurial tests on cacao have shown very great initial variations in the plots, which have to be fully determined before the effects of the manures be known.

Some interesting figures will be found on the subject of individual yields of cacao trees. The total number of individual trees investigated was over 300 at the beginning.

Port Inspection.

The inspection of cacao at ports was commenced on January 1st, 1927, and has been continued throughout the year, and much invaluable information has been outlined. Thanks are due to the exporters for their unanimous consent to submitting their exports to sampling for this examination.

The papers included in this Yearbook cover only the methods and errors in sampling. The information obtained by the actual inspection is submitted to the shippers concerned.

Other work described in the papers includes investigations carried out into the causes of certain of the defects of cacao beans, and also into certain pests and diseases.

Coconuts.

The palms at the Atuabo coconut plot began to come into bearing in quantity during the year. The plantation was duly equipped with a dryer for using artificial heat. The paper given shows the results with the dryer, which are not so good as may be expected after the present accumulated crop containing many germinated nuts is worked off.

Now that actual sales of copra are being made, the people in the neighbourhood are taking more interest in the crop.

Sisal Hemp.

The plantation has not had a successful year, since a lengthy stoppage had to be made in the working of the mill on account of leaf shortage.

During the working time, the results as to production and costs were quite near the average.

Cotton.

The ginnery at Tamale has been completed, but the results from the first distribution of cotton seed were not good. The people simply did not use the seed. The reasons are, however, known, and as they are in no way an agricultural problem, they are being dealt with, by the officers concerned.

There seem no purely agricultural reasons (as regards soil, climate or the knowledge or ability of the people) why the crop should not succeed.

The Department has initiated tests with seed imported from Nigeria against that used by the people from time immemorial, and it is a pleasing indication that the people have recognised the superiority of the distributed seed. Plots have been laid down for the purpose of increasing this superiority by the selection of suitable plants, and their propagation in succeeding years in order to establish a type specially suited to Northern Territories, in the same way as has been done in Nigeria.

Limes.

The Lime area is now regarded as complete, and all that remains in order to establish the beginning of the lime-juice industry, is the building and operation of the mill referred to last year.

Conferences.

The Department was represented at the First West African Agricultural Conference held at Ibadan, Nigeria, in March, the First International Soil Congress, held at Washington in July, and the First Imperial Agricultural Research Conference, held in London in October, 1927.

Résumés of the first and last are given in these notes. In regard to the second, some delay has taken place in the publication of the complete range of resolutions which were passed, hence a note on the Congress is being held back until the 1928 Yearbook.

Organisation.

The agricultural policy of the Government and the organisation of the Department have been the subject of consideration by a Departmental Committee which sat from April to July. The Report of this Committee is now being considered by Government.

PAPER No. II.

REPORT ON THE IMPERIAL AGRICULTURAL RESEARCH CONFERENCE, 1927.

(*The delegates from the Department of Agriculture of the Gold Coast to the Conference were* G. G. AUCHINLECK, R. H. BUNTING, W. H. PATTERSON, *and* A. C. MILES.—*Editor.*)

2. Diary.

The following meetings were attended, and visits made, by one or more of the delegates.

29th September.—Meeting of Colonial delegates with Lord Lovat's Committee on Agricultural Research and Administration.

4th to 7th October.—Daily plenary sessions of Conference for preliminary consideration of administrative and technical questions, and appointment of an administrative commission, and technical committees, to discuss questions in detail.

10th to 13th October.—Meetings of the Plant Pathology, Plant Breeding, Entomology, Agricultural Economics, Committees, and a combined meeting of the Fruit, Plant Pathology, and Entomology committees.

14th October.—Visit to the National Institute of Agricultural Botany, Cambridge.

15th October.—Visit to the Animal Nutrition Institute, Plant Breeding Institute, School of Forestry, and University farm, Cambridge.

16th October.—Visit to the Botanical Gardens, Cambridge.

17th October.—Visit to the Bio-Chemical Laboratory, Low Temperature Research Institute, Molteno Institute of Parasitology, Balfour Institute of Genetics, Departments of Botany and Zoology, Cambridge.

18th October.—Visit to Messrs. Chivers, jam factory, Histon.

19th October.—Visit to the Imperial Chemical Works, Billingham.

20th October.—Visit to the Department of Botany, Edinburgh University.

21st October.—Visit to the Scottish Plant Breeding Station, and the Plant Registration Station, Corstorphine.

22nd October.—Visit to Messrs. Gracey Bros.' Cold Store, Belfast; the Northern Ireland Plant Breeding Station and Animal Diseases Research Station, Stormont; and the Linen Research Institute, Lambeg.

26th to 28th October.—Daily plenary sessions of Conference to consider reports of administrative commission, and technical committees. Meeting of Economic Botanists.

29th October.—Visit to the Rothamsted Experimental Station, Harpenden.

30th October.—Visit to the Imperial Institute, and Royal Horticultural Society Gardens, Wisley.

31st October.—Visit to the Imperial College of Science (Plant Physiology Research Institute), South Kensington; the Royal Botanic Gardens, Kew; and Imperial Institute.

1st November.—Visit to the East Malling Research Institute.

2nd/3rd November.—Visits to the North Wales University College, Bangor, and the John Innes Horticultural Institute, Merton.

4th November.—Visit to the Agricultural and Horticultural Research Station, Long Ashton, Bristol.

7th November.—Meeting of West African Delegates with Major Elliot of the Empire Marketing Board.

3. Composition of Conference.

The personnel of the Conference consisted of nearly 200 members from all parts of the Empire, and included representatives of the Colonial and Dominions Offices, Ministries of Agriculture for Britain and Northern Ireland, Scottish Board of Agriculture, Agricultural and Medical Research Councils, Imperial Bureaux of Entomology and Mycology, Empire Marketing Board, Department of Overseas Trade, Board of Education, Imperial Institute, Royal Botanic Gardens (Kew), Royal Agricultural Society of England, Empire Cotton Growing Corporation, Linen Industry Research Association, etc.

Lord Bledisloe, of the Ministry of Agriculture and Fisheries, was appointed Chairman.

4. Benefits Derived.

It will be readily understood from the representative composition of the Conference that, apart from the future benefits which may be expected to result from the business enacted at the formal meetings, much inspiration and beneficial knowledge was gained by informal conversations with workers from the varied countries represented, as well as from contact with those in administrative authority at home. There are also to be recorded the no less valuable stimuli and knowledge gained by visits to the various British research centres, where, by demonstrations and technical addresses, something was learnt of results achieved and of work in progress, in all the diverse and minute branches of the agricultural sciences.

The Conference concerned itself chiefly with the consideration of fundamental research, such as is intended to result in long-range, rather than local, application. For those whose work is restricted to the advisory and "general practitioners'" provinces of agricultural science, the broadening effect of such an aspect was particularly gratifying.

5. Administrative Recommendations.

The Conference, being in no way an executive body, could not do more than formulate advice and recommendations to the Governments concerned. Briefly stated, the recommendations made on administrative questions were as follows:—

i. Establishment of Central Research Stations in Tropical and Sub-Tropical Countries.—The following provisional programme for the establishment of new Central Research Stations was recommended, subject to modification by the proposed Colonial Agricultural Council, and in addition to those already established at the Imperial College of Tropical Agriculture, Trinidad; and at Amani, East Africa, and to that proposed by the Australian Government for North Queensland:—

Ceylon, probably for tea and rubber research.
East Africa, probably for animal diseases.
West Africa, probably for vegetable oils, oil seeds and nuts.
Federated Malay State (or Middle East), probably for coconuts and oil palms, irrigation, and veterinary research.

It was recommended that the proposed stations should (1) satisfy Imperial rather than local requirements; (2) confine themselves to long-range and wide-range research, *i.e.*, to problems requiring prolonged investigation, and to those problems which arise in more than one territory; (3) deal individually with particular fields of agriculture, rather than that they should be instituted for geographical reasons; (4) reinforce, but in no way substitute, the proper scientific work of local Departments of Agriculture; and (5) that they should not undertake teaching work.

ii. Recruitment and Training of Officers.—The Conference considered that a unified system of recruitment and training for agricultural and scientific officers for the whole of the Empire was impracticable; the following conclusions and recommendations under these heads were therefore made for the Colonial service :—(1) that the dearth of recruits made immediate reinforcement in recruitment and training essential; (2) that the standard required for (*a*) specialist officers be an honours training in the pure sciences, including at least one biological science, and an adequate knowledge of agriculture; and for (b) agricultural officers, wide agricultural knowledge, a practical outlook, administrative ability, and sufficient scientific knowledge for the full utilisation of scientific results, and for collaboration with specialist officers; (3) that character and health be considered of first importance; (4) that adequate emoluments, facilities for work, and satisfactory superannuation arrangements were necessary for purposes of recruitment and efficiency; (5) that the Colonial Office Agricultural Scholarship Scheme, if strengthened and suitably modified to include veterinary science, might be expected to meet Colonial requirements for the present.

iii. Study-Leave and Interchange of Officers.—The Conference came to the following conclusions :—

(1) that facilities of study-leave for officers were essential to the success of the agricultural service;

(2) that " existing facilities for study-leave are, in general, inadequate," and that " specific financial provision, and appropriate increases in staff to make study-leave possible, are an urgent necessity ";

(3) that a routine interchange of officers was to be deprecated, but that occasional interchange would bring many benefits; and

(4) that existing facilities for the beneficial interchange of workers were inadequate, mainly because of financial difficulties.

iv. Establishment of Bureaux and Correspondence Centres.—The establishment of the following as new imperial bureaux on the lines of those existing for entomology and mycology was recommended :—

(1) Soil science, to be attached to the Rothamsted Station.

(2) Animal nutrition, to be attached to the Rowett Institute, Aberdeen.

(3) Animal health, for immediate establishment in London.

In addition to the above bureaux, it was recommended that clearing stations of information, to be termed correspondence centres, should be established for the following subjects :—

(1) Animal genetics, to be attached to the University of Edinburgh.

(2) Agricultural parasitology, to be attached to the Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.

(3) Plant genetics for herbage plants, to be attached to the Welsh Plant Breeding Station, Aberystwyth, and for other crops, to the Cambridge University.

(4) Fruit production, to be attached to the Research Station, East Malling.

N.B.—The functions of a correspondence centre are intended to be the collection, collation, and dissemination of information of a scientific and technical character, to reply to enquiries on scientific and technical problems, and particularly to facilitate intercourse among workers.

The Conference considered that the establishment of a bureau of general agricultural research was not practicable, and that the time would not be ripe for the establishment of either bureaux or correspondence centres on any other subjects than the above, until such subjects were sufficiently defined.

The Conference further recommended that (1) the funds made available for the establishment of the proposed bureaux and correspondence centres should be administered by an Authority representative of the contributing Governments; (2) each bureau should be administered by a technical committee of experts nominated by the Governments concerned, and that (3) each correspondence centre should, as far as practicable, be conducted similarly.

v. Conferences of Research Workers.—It was decided that the next Imperial Agricultural Research Conference be held in Australia in 1932, and it was recommended that specialist and regional conferences should be held at fairly frequent intervals.

6. Technical Recommendations.

The Conference agreed *nem. com.* to support the following recommendations and suggestions proposed by the technical committees:—

i. Plant pathology and mycology :—

(1) that the reports already submitted each month appeared to be all that was necessary to meet the demand of the International Institute of Agriculture at Rome for early official notification of plant diseases and pests;

(2) that lists of plant diseases occurring in each country of the Empire be prepared, and revised when necessary, by Governments concerned and published and distributed by the Imperial Bureau of Mycology;

(3) that, with a view to uniformity in plant disease nomenclature, the attention of Empire mycologists be called to the list of plant disease names now under preparation by the British Mycological Society, and that the Society should circulate the list to all Governments of the Empire;

(4) that the Imperial Bureau of Mycology be asked to prepare, and when necessary to revise, a list of books and periodicals to be regarded as the minimum requirements for a Government Mycologist, and that a copy of the list be forwarded to the departments concerned;

(5) that overseas Governments supply copies of all officially published papers and bulletins on mycology and plant pathology to Institutions mentioned in a list to be prepared by the Imperial Bureau of Mycology; and

(6) that, in view of the urgency of the problems of virus diseases, no time should be lost in the provision of funds for the more extended study of the nature of virus diseases in plants.

ii. Entomology :—

(1) that each entomological service in the Empire should be represented by an entomologist at the quinquennial entomological conferences, and that sufficient delegates should be sent from the larger entomological services to represent their various activities;

(2) that such conferences occasionally be held in other Imperial centres than London;

(3) that travelling fellowships be established for entomologists engaged on special lines of investigation;

(4) that the necessity of paying more attention to the biological control of insect pests should be emphasised, as well as the need of giving further assistance to the parasite work of the Imperial Bureau of Entomology; and

(5) that the importance of training and research in pure entomology should be emphasised.

iii. Fungicides and insecticides :—

(1) that an investigation of the whole chemical field should be undertaken by chemists, in collaboration with entomologists and plant pathologists, in order to supplement the limited number and relatively inefficient substances at present used for control of diseases and pests.

iv. Fruit :—

(1) that the most urgent problems in fruit cultivation requiring research were (*a*) the study of stock and scion, and their inter-relation; (*b*) surveys of fruit areas to determine the relation of various factors to tree growth and fruitfulness; (*c*) chemical studies relating to the tree and its crop; and (*d*) the associated physiological studies.

(2) that, while much research work on these subjects had been done, such work should be greatly extended, and additional workers employed on these problems.

v. Preservation and transport :—

(1) that all parts of the Empire as well as Great Britain should undertake the solution of fundamental problems relating to the preservation and transport of agricultural produce, *e.g.*, tropical fruits;

(2) that the scientific, as distinct from the economic inspection of cargoes from overseas should properly be carried out by representatives of the country of origin, to whom the Department of Scientific and Industrial Research would lend their assistance; and

(3) that each research centre of the Empire should forward all its publications on the preservation and transport of food to the Low Temperature Research Station at Cambridge, which station should periodically publish and distribute lists of elaborated titles of useful publications on those subjects, and that the operation of such a scheme should be reviewed later.

vi. Soils and fertilisers :—

(1) that a memorandum on soil classification be circulated by the proposed bureau of soils, for the guidance of soil chemists throughout the Empire;

(2) that where soil survey data are to be published, the mechanical analysis of soils should be made by the International method, or by some other method which has been shown to give the same result, it being recognised that certain soil types require special methods, details of which methods should be worked out by the soil bureau for circulation;

(3) that the soil bureau should prepare and circulate a memorandum on the fundamental principles which should govern all fertiliser trials throughout the Empire; and

(4) that the soil bureau should prepare and circulate suitable suggestions for experimental work, and recommendations regarding soil deterioration due to shifting cultivation, disafforestation, etc.

vii. Agricultural economics :—

(1) that the necessity for a systematic and continuous study of economic conditions, as a means of promoting prosperity in Empire agriculture, should be emphasised;

(2) that the Governments of the Empire should secure the services of whole-time agricultural economists on the staffs of their Departments of Agriculture.

(3) that the attention of the Universities of the Empire should be directed to the dearth of technically trained workers in this field;

(4) that the principal methods of investigation in the economics of farm production should be (*a*) cost accounting, (*b*) farm surveys;

(5) that economic surveys should be considered as desirable, especially in the framing of agricultural policies with particular reference to the development of new areas;

(6) that among the chief objectives of marketing research should be (*a*) abolition of waste, and (*b*) the lessening of price fluctuations, for which objects continuous research is required in each country;

(7) that the collection of agricultural statistics should be attempted in all countries of the Empire where such is not already being done, and that, where necessary, Governments should assume the power to do so; and

(8) that all Governments of the Empire should co-operate to the fullest possible extent in the project of the World's Agricultural Census, 1930-31.

viii. Animal health, nutrition and genetics, and dairying.—The vast importance of these subjects to the Empire was agreed by the Conference, and recommendations were made chiefly for the closer co-operation of workers, and for the extension and increase of research work.

7.—

In general, it may be recorded that, throughout the meetings and visits, an atmosphere was constantly present which emphasised the unmistakable necessity for fundamental scientific research as a basis, not only for the improvement of production and its cognate subjects, but also for the economics of agriculture. Although this aspect may prove, in many of its details, to be at present too idealistic for local application, the Gold Coast may be expected to share in the benefits to be derived from the solidification of scientific effort throughout the Empire. The machinery set up by the Imperial Government, *e.g.*, The Empire Marketing Board, the proposed chain of research stations, the new bureaux, the periodical foregathering of workers from all parts of the Empire, demonstrate not only the recognition of the fundamental importance of agriculture, but also the desire for solidarity of effort within the Empire, and the prospect of mutual inter-imperial assistance.

PAPER No. III.

Resolutions passed by

THE FIRST WEST AFRICAN AGRICULTURAL CONFERENCE, 1927.

(*The delegates from the Department of Agriculture of the Gold Coast to the Conference were* G. G. AUCHINLECK, R. H. BUNTING, G. S. COTTERELL, R. COULL *and* A. W. PATERSON.)

Origin.

The First West African Agricultural Conference was held from March 4th to 10th, 1927, at Moor Plantation, Ibadan, the headquarters of the Nigerian Department of Agriculture. In June, 1925, the Second Imperial Entomological Conference in London had passed a resolution recommending that periodical meetings of Entomologists, Mycologists and other scientific officers should be held in various Dominions and Colonies. The Governors of Nigeria, the Gold Coast, Sierra Leone and the Gambia decided to act on this resolution, on condition that the basis of the West African meeting was broadened so as to include all lines of work carried on by local Departments of Agriculture.

Aim.

The West African Conference has therefore come into line with Agricultural Conferences elsewhere, such as the West Indian, the Pan-Pacific, and the Imperial Agricultural Conferences. The main aim of such conferences must be the development of sound agricultural policy in the countries they serve, and the numerous specialist lines of work which are contributory to the general aim fall naturally into correct perspective if the general aim is kept in mind.

Papers Read.

Discussions at the West African Conference centred around the following papers which were prepared by delegates:—

1. *The Oil-palm Industry and its problems in Sierra Leone,* by Messrs M. T. Dawe and F. J. Martin.
2. *The Oil-palm Industry in Sumatra and Malaya,* by Messrs G. G. Auchinleck and H. B. Waters.
3. *The Extraction of Oil-palm Products,* by Mr. A. C. Barnes.
4. *The Grading of Cotton, Cocoa and Palm Products,* by Messrs. A. J. Findlay and E. McL. Watson.
5. *Some Aspects of the Gold Coast Cocoa Industry,* by Mr. A. W. Paterson.
6. *Diseases of Cocoa, and Measures for their Control,* by Mr. R. H. Bunting.
7. *Pests of Cocoa in the Gold Coast,* by Mr. G. S. Cotterell.

PLATE I.

1 F. J. MARTIN SL
2 A. C. BARNES N
3 E. M. WATSON N
4 T. LAYCOCK N
5 M. T. DAWE SL
6 O. T. FAULKNER (Chairman) N
7 G. G. AUCHINLECK GC
8 P. H. LAMB N
9 E. HARGREAVES SL
10 R. H. BUNTING GC
11 O. B. LEAN N
12 F. D. GOLDING N
13 H. ROEBUCK N
14 H. B. WATERS N
15 H. G. POYNTER N
16 B. BROWNE N

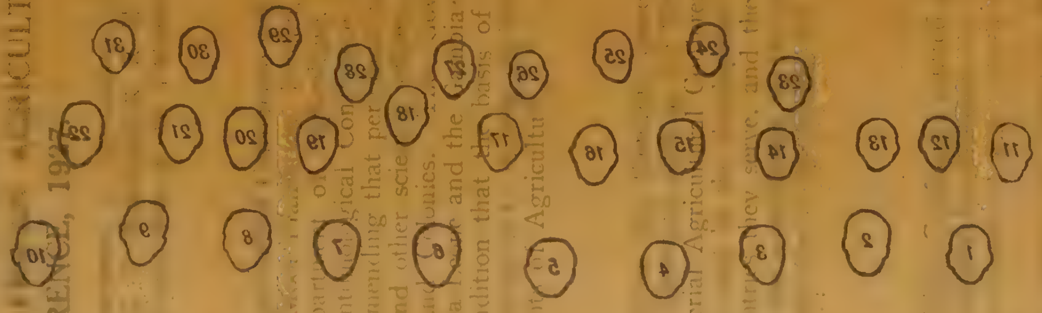
17 T. O'N. HEWITT N
18 A. W. PATERSON GC
19 G. H. JONES N
20 A. G. G. HILL N
21 O. S. SWAINSON N
22 G. S. COTTERELL GC
23 R. COULL GC
24 E. de B. DIAMOND N
25 R. V. D. WHITE N
26 T. THORNTON N
27 C. T. LEWIN N
28 C. H. WRIGHT N
29 T. R. V. SMYTHE N
30 F. C. DEIGHTON SL
31 S. H. GILBERT N

N = NIGERIA
GC = GOLD COAST
SL = SIERRA LEONE

[Photo by A. C. Barnes

FIRST WEST AFRICAN AGRICULTURAL CONFERENCE,
IBADAN, NIGERIA,
1927

PLATE I.



1	F. J. MARTIN	SL
2	A. C. BARNES	N
3	E. M. WATSON	N
4	T. LAYCOCK	N
5	M. T. DAWE	SL
6	O. T. FAULKNER (Chairman)	N
7	G. G. AUCHINLECK	GC
8	P. H. LAMB	N
9	E. HARGREAVES	SL
10	R. H. BUNTING	GC
11	O. B. LEAN	N
12	F. D. GOLDING	N
13	H. ROEBUCK	N
14	H. B. WATERS	N
15	H. C. POYNTER	N
16	B. BROWNE	N
17	T. O'N. HEWITT	N
18	A. W. PATERSON	GC
19	G. H. JONES	N
20	A. G. G. HILL	N
21	O. S. SWAINSON	N
22	G. S. COTTERELL	GC
23	R. COULL	GC
24	E. de B. DIAMOND	N
25	R. V. D. WHITE	N
26	T. THORNTON	N
27	C. T. LEWIN	N
28	C. H. WRIGHT	N
29	T. R. V. SMYTHE	N
30	F. C. DEIGHTON	SL
31	S. H. GILBERT	N

N NIGERIA
GC GOLD COAST
SL SIERRA LEONE

[Photo by A. C. Barnes

FIRST WEST AFRICAN AGRICULTURAL CONFERENCE,
IBADAN, NIGERIA,
1927

8. *Some Insect Pests of Sierra Leone*, by Mr. E. Hargreaves.
9. *Nigerian Insect Pests of Cotton*, by Messrs. F. D. Golding and O. B. Leans.
10. *Fungoid Pests of Cotton*, by Messrs. T. Laycock and G. H. Jones.
11. *The Maintenance of Soil Fertility by Rotational Green Manuring*, by Messrs. A. G. G. Hill and H. B. Waters.
12. *Soil Investigations, Sierra Leone, with special reference to a Soil Survey of British West Africa*, by Messrs. F. J. Martin and H. C. Doyne.

These papers, together with the major outlines of discussion, have been printed by the Nigerian Government in a volume entitled "Proceedings of the First West African Agricultural Conference, Ibadan, 1927." Copies of the volume available at the office of the Director of Agriculture, Accra, Gold Coast.

Other Discussions.

A very full discussion took place on the future of the oil-palm industry and the likelihood of severe competition from the plantations which are being established in the East. Other debates dealt with the establishment of a West African Agricultural College, the collection and publication of accurate statistics of agriculture, and the fostering of trade with Canada, South Africa and the United States of America. The chemists present sat in committee and prepared the general outlines of a Soil-Survey of British West Africa, and the entomologists submitted proposals for systematic co-operation and exchange of information. Certain staff matters were also fully discussed.

Resultant Resolutions.

The following resolutions were passed by the Conference, to be submitted to the Governments concerned :—

RESOLUTION No. 1.

That this Conference has duly considered the question of future Conferences, in regard to the frequency with which it would be convenient that it should be held and the Colonies in which it should in turn take place, and recommends :—

(*a*) That for the coming six years it be held biennially.

(*b*) That after that period it be held once in every three years.

(*c*) That it takes place in the other three Colonies (with the approval of the Governments concerned) in the following sequence :—in 1929 in the Gold Coast, in 1931 in Sierra Leone, and in 1933 in the Gambia.

RESOLUTION No. 2.

That this Conference wishes to recommend that an Entomologist be sent to Fernando Po and St. Thome to investigate the reasons for the scarcity of Sahlbergella spp. in those islands, including the possibility of control by natural enemies.

RESOLUTION No. 3.

(*a*) That co-operation should be established between the Entomologists of the three West African Departments of Agriculture represented at this Conference.

Co-operation would include such matters as :—

(i) Exchange of annual programmes of work prior to the commencement, and of summaries of results of recent work, before publication if necessary.

(ii) Immediate notification of the discovery of pests and of natural enemies.

(iii) Exchange of any required specimens and publications.

(iv) The preparation of a list of the host plants and natural enemies of West African insects, with special sections concerning termites and ants.

(v) A study of the food of West African birds (insectivorous and others).

(*b*) We would like to emphasise the value of co-operation between research officers in the same Department.

(*c*) We suggest that at the next Conference an Entomological division should be formed, that papers should be circulated before its commencement, but that discussion should take place at the Conference. It being taken for granted that any officers, other than Entomologists, who wish would attend.

RESOLUTION NO. 4.

The Conference recommends that the West African Colonies exchanging their publications should forward to each other several copies of each publication. It is suggested that for the present twelve copies be sent to Nigeria, the Gold Coast and Sierra Leone, and six to the Gambia.

RESOLUTION NO. 5.

The Conference has duly considered the question of the appointment of an Oil Palm Expert at the joint expense of the Nigerian, Gold Coast and Sierra Leone Governments, and is of opinion, in view of this Conference which will now take place at regular intervals, and the frequent interchange of information on Oil Palm research which has been arranged between the corresponding officers of the respective Governments, that there is now no need for such an appointment.

RESOLUTION NO. 6.

That in the opinion of this Conference it is most desirable that, within the next twelve months, a mission composed of two officers from the West African Departments of Agriculture should visit the Belgian Congo to study the methods there adopted for the development of the oil-palm and the exploitation of its products, and that preferably one of the officers chosen should be one of those who recently went on a similar mission to Sumatra.

RESOLUTION NO. 7.

That this Conference has carefully considered the question of the development of trade between the British West African Colonies and Canada, raised in Despatch No. 3, of the 22nd February, 1927, from the Governor of Sierra Leone to the Governor of Nigeria, and accompanying Sessional Paper No. 1 of 1927, and is of opinion that the British West African Governments should conjointly take active measures to develop the markets of the United Kingdom, Canada, the United States and South Africa, and that a West African Trade or Commercial Intelligence Bureau should be established in each country where the prospects of increasing trade may justify same. It is also of opinion that the Governments should undertake suitable trade propaganda, such as participating in the Canadian National and other appropriate Exhibitions.

The Conference therefore recommends :—

(*a*) That a Joint West African Commercial Intelligence Bureau be established in the United Kingdom at London.

(*b*) That a branch Bureau be established in Canada at Montreal provisionally for the period of five years, on the expiry of which the results would be reviewed to ascertain if they justify the permanent establishment of the Bureau.

(*c*) That the four British West African Colonies participate in the Canadian National Exhibition in 1928, and successive years during the continuance of the West African Bureau at Montreal.

(*d*) That the four West African Governments cause an investigation to be made into the possibilities of the further development of the markets in the United States and South Africa for West African produce, and also as to the desirability of establishing in those countries a West African Commercial Intelligence Bureau.

RESOLUTION NO. 8.

The Governor of the Gold Coast has asked that the Governor of Nigeria place before this West African Agricultural Conference a proposal for the establishment of an Agricultural College for West Africa.

This Conference is of opinion :—

(*a*) that a West African Agricultural College is necessary;

(*b*) that the natural centre for such a college appears to be Nigeria;

(*c*) that in founding the college it is recognised that its work in the beginning should deal primarily with training of the Senior African Staff;

(*d*) that a staff be provided for the college separate from and extra to the staff of existing Departments;

(*e*) that in numbers and training the staff provided be adequate both for the needs of the college and to ensure the prosecution of those branches of research work in agricultural science which cannot be normally carried out by the existing local Departments of Agriculture.

RESOLUTION NO. 9.

This Conference recognises the necessity for the provision of facilities for fundamental scientific research in the West African Colonies, and hopes that adequate provision for such research will be made in connection with the scheme for the proposed West African Agricultural College.

RESOLUTION NO. 10.

(*a*) The Chemical Committee consider that a soil survey of British West Africa is desirable, and should be undertaken by the Agricultural Chemists in and for each Colony.

The survey which the Committee have in mind is of the nature of routine examinations undertaken in collaboration with other members of the agricultural staff.

(*b*) The Committee has considered methods of sampling and analysis, and has prepared a report embodying certain methods which they suggest should be adopted by the various chemical laboratories.

(*c*) The Committee wish to emphasise that a great deal of work is entailed in a soil survey, and that the rate of progress will depend entirely on the staff, accommodation and equipment placed at the disposal of the respective Chemical Departments.

(*d*) The Committee recommend that the following expression of opinion should be forwarded by this Conference to the Agricultural Research Conference to be held in England this Autumn (1927) :—

(i) The Chemical Committee of the West African Research Conference is of the opinion that a Bureau of Soil Science, including a tropical section, would be of great value.

(ii) The Committee suggest that the functions of such a Bureau should include :—

(*a*) The collection and collating of the results of soil investigations in the various colonies, and the publication of a Review comparable with the Reviews of the Bureaux of Entomology or Mycology.

(*b*) Machinery for assisting Agricultural Chemists in the Colonies to carry forward research on fundamental problems beyond the point possible in colonial laboratories where staff and other facilities are limited. It is suggested that the existing research institutions, such as Rothamsted, could be utilised to carry out work of the nature indicated. What is wanted is some method of getting the research worker in the Colony into direct contact with any specialist engaged in investigating the particular problem on which information is needed.

(*c*) The publication of approved methods of classification and analysis of soil, so that the accumulation of the results of soil investigations in the Colonies and Dominions will eventually resolve itself into a soil survey of the Empire, a survey which should prove of great value and importance. (The Chemical Committee forward a copy of methods approved for use in West Africa, for submission to any Committee appointed by the Research Conference to study this question.)

RESOLUTION NO. 11.

In view of the necessity for reliable statistics of agriculture in West Africa, the Conference is of opinion that the Governments concerned should secure from their Directors of Agriculture at an early date an expression of opinion as to the staff and machinery needed to provide for a reasonably accurate system of agricultural statistics.

RESOLUTION NO. 12.

This Conference recognises that the West African Oil Palm Industries are threatened by the establishment in the Far East of well organized plantations and factories for the production of palm fruit and the extraction of its products.

It is felt that this is likely to lead to a reduction in the price of palm oil relative to other vegetable oils, which may cause the value of West African palm oil to fall to a figure such as to discourage the production of low grade palm oil for export.

Should this occur, it is realised that there is possibility of some decrease in the quantity of palm kernels prepared annually for export from West Africa.

In view of this danger efficient steps should be taken to organise the industry so as to prevent the present waste involved by native methods of preparation, and it is recommended that, with due regard to the safeguarding of native interests, the establishment in selected districts of a limited number of factories of approved design and capacity for the extraction of oil palm products should be actively encouraged.

It is further recommended that the study of varieties of the oil palm and their yields, and the breeding of new strains should be prosecuted.

The Conference recognises that though it may be possible to introduce to a limited degree improved methods for the small scale extraction of palm oil by natives, it is not likely that such work will result in a greatly increased production of oil of better quality for many years.

RESOLUTION NO. 13.

This Conference is of opinion that the Governments of the West African Colonies should consider the advisability of providing a system of selection posts in the local Departments of Agriculture on the basis established in India, Malaya and Ceylon;

(*a*) that such post be regarded as an extension of the normal salary scale of technical officers.

(*b*) that these posts should not be necessarily restricted to any one branch of the senior staff of the Departments concerned.

RESOLUTION NO. 14.

This Conference recognises that the training, qualification and experience of Agricultural Officers should not be inferior to those of other scientific research officers in their respective branches, and recommends that the initial salaries of Agricultural Officers should be raised to those now granted to Research Officers.

PAPER No. IV.

OUTLINES OF AGRICULTURAL POLICY IN THE GOLD COAST.

(A lecture given on January 19th, 1928, to Cadets of the Political Service, by G. G. AUCHINLECK, *Deputy Director of Agriculture, Chairman of Committee on Agricultural Policy and Organisation.)*

In comparison with most other Government Departments, the local Department of Agriculture is young. Provision was first made in the Estimates for 1889, when £300 were included for founding the Botanic Gardens of Aburi, and the first officer, a Curator, arrived in the Colony on March 16th, 1890.

It is of importance to discuss the reasons which led to the foundation of Botanic Gardens as a means of developing agriculture, since the procedure has had a very distinct effect on subsequent developments of policy. The usual procedure nowadays is to found Agricultural Experiment Stations, but in early days most nations created Botanic Gardens. Thus the Dutch founded Buitenzorg Gardens in Java in 1817, the French Governor of Mauritius started Pamplemousses Gardens previous to 1800, and the British founded Peradeniya Gardens in Ceylon in 1822.

In the beginning, Governments limited their agricultural policy to importing and observing exotic plants, assuming that private enterprise would know how to use them to the best advantage. This earlier work resulted in the exchange between countries of numerous plants of value. In the case of the Gold Coast, we find that cacao was obtained from Venezuela through Fernando Po, and Hevea rubber from Brazil. Nim, Cassia and Casuarina trees which are now used to afforest Accra were obtained from Southern India, Siam and Australia respectively. As recently as last month, a new plant, Hydnocarpus, from which Chaulmoogra oil, used as a cure for leprosy, is obtained, was received locally from Siam.

PAST POLICY TOO LIMITED.

The value of this work is obvious, but it can be carried out more thoroughly and on a more adequate scale on an Experiment Station. In a Botanic Gardens the work is limited necessarily to one or at most two or three specimens of each tree. This fact, coupled with the fact that executive agricultural officers are a very recent development and that earlier work had to be carried out by horticultural men or by specialists in single lines of science, has led to a very real misunderstanding. Only now are Governments realizing that their policy must go far beyond the mere introduction of new plants and the publishing of purely botanical information.

This limited policy was adopted in the Gold Coast much later than in most other tropical countries, and it has persisted longer. Work of the kind formerly carried out in Botanic Gardens is now performed in public gardens or by botanical exploration parties, and, if it enters into Government policy at all, it forms a very minor part of agricultural policy. Nowadays it is as logical to limit agricultural policy to the importation of single specimens of new plants as it would be to stimulate stockbreeding by founding zoological gardens. The kind of work performed by botanic gardens is analogous to that of zoological gardens, and it bears the same relation to agriculture as the latter does to live stock farming.

In order to understand the type of work now required from the Department of Agriculture, one must rid oneself of several misconceptions and misunderstandings which are current locally. In the first place, ornamental gardening and horticulture are not part of the duties of the Department, and they must be provided for separately. In the second place, the importation of economic plants from other countries is only the first step; as the subsequent testing of such plants on an adequate agricultural scale is expensive and laborious, only those plants should be tried which are reasonably certain to be of value.

In the third place, it should be realised that investigation into the commercial possibilities of unknown forest plants is the duty of a botanical explorer, a type of officer whose work belongs to the sphere of "long range research," and who is not likely to be required by the Department of Agriculture for many years to come. Finally, the naturalisation of European vegetables and fruits is not an urgent problem of local agriculture, however interesting and gratifying it may be to European residents, and this kind of work must be done by private enterprise. Any efficiently conducted general store in other tropical countries stocks a supply of vegetable and flower seeds for the needs of local residents, and one may hope to see the same thing done here in due course.

THE PROBLEM OF THE TROPICS.

The tropical belt of the world is peopled by races who have been severely handicapped in the past by unfavourable climatic conditions, and who will continue to be handicapped in the future. They do not produce their full quota of the world's necessities and luxuries, and many of these luxuries and necessities belong to and can be grown only in the Tropics. Cacao, rubber, rice, cotton, cane-sugar, vegetable oils and fats such as coconut and palm oils, coffee, tea, balata, gutta percha, quinine, tobacco, manila hemp and sisal are a few important examples. Some of these were unused weeds a century or so ago, but are now recognised agricultural crops, unfamiliar to the new-comer to the Tropics, but understood by tropical Departments of Agriculture.

The general agricultural and climatic requirements of the commoner tropical crops are well understood. In almost every case the general principles of their cultivation have been worked out by Departments of Agriculture, or by European settlers or European

planting companies in the Tropics. The problem which faces tropical Departments of Agriculture is not the exploitation of totally new products, but the development of existing ones, and the increasing of the per capita output of tropical races. The low standard of output of tropical races as compared with that of temperate climate races can be seen at a glance by comparison of figures of exports. In the Gold Coast, for example, it is about £8 per head, in Malaya, where European plantations are the main agricultural features of the country, it is over £50.

The problems which the local Department of Agriculture has to solve, therefore, is to find out what factors cause the low per capita output of the people and then to devise means for removing them. Only in rare instances do these factors appear to be agricultural: some are educational, some economic, and some political, and no amount of purely technical agricultural skill in field or laboratory can remove them unaided.

This point is of great enough importance to warrant illustration by some recent local examples. The experiment of growing sisal on the Accra plains, and of preparing the commercial fibre, was rightly required of the Department of Agriculture, and the experiment was efficiently carried out: economic factors, labour conditions and peculiarities of land tenure, on which evidence does not appear to have been fully obtained from administrative officers, will probably prevent sisal from becoming a local industry.

There are no agricultural difficulties in the way of efficient cultivation of oil-palms locally, but there are several economic, educational and political factors acting as handicaps or obstacles, which can be cleared away only by administrative action. Coconuts grow rapidly on the sandy coastal strip and in some places inland, and are being planted on communal land by the Department of Agriculture: the problem of extending the industry is an economic and administrative, not an agricultural, one.

Two other examples of a different kind can be mentioned. The work of the Plant Pests Inspectorate from its very inception has been technically efficient and energetically carried out: it was brought virtually to a standstill because the ground had not been adequately prepared beforehand from the administrative and political aspects. Still more recently, the Department has carried out, efficiently and accurately, an extensive series of investigations into the incidence of defects in exported cacao: the utilisation of this information in order to improve the quality of local shipments is not purely an agricultural problem: it will require unstinted help from local merchants, chiefs and political officers, and in addition carefully considered administrative and possibly legislative action by Governments.

THE POLITICAL OFFICER AND AGRICULTURE.

The Department of Agriculture is very rarely faced with a purely technical problem excepting in the course of experimental work in the field or laboratory. Any problem of development is a

complex one in which educational, economic and political factors play a greater part than purely agricultural questions. Consequently, the collaboration of more than one Department is nearly always necessary. Strictly speaking, the agricultural officer is responsible only for purely technical agricultural matters, just as the Public Works Engineer is responsible for making a road and not for evolving and giving effect to a general policy of development of transport. Naturally, in both cases some advisory functions must creep in, but actual responsibility ends with the technical work.

This point must be emphasised, because in the past the agricultural officer has very rarely been judged on the merits of his technical work. He has been held responsible for solving problems of policy and not agricultural problems. This has been illustrated in the cases of sisal, coconuts, oil palms, plant pests inspection and cacao grading, and it applies to other cases as well. In a matter of such general interest and vital importance as agricultural development is locally, everyone assumes the right to criticise, and is none too careful in apportioning any blame he may think necessary. The Department of Agriculture has hitherto been a most convenient whipping-horse for deficiencies in any matter related to agriculture.

The fact of the matter is that agricultural policy is a function of Government in general and not of one Department. Team work between Departments, farmers and merchants is the only means of obtaining satisfactory results, and in this team work the responsibility of the Department of Agriculture must be limited to technical agricultural work and technical agricultural advice.

The administration of Government affairs of the country rests on the political district, and one naturally turns to this fact in considering the best means of evolving and carrying out an agricultural policy. The Committee on Agricultural Policy and Organisation, which sat in 1927, and whose Report will be available shortly as a Sessional Paper, discussed this matter fully. They recommended the establishment, under the Chairmanship of the District Commissioner, of a permanent District Agricultural Committee in each district considered suitable for it. The decision as to the feasibility of establishing and using a Committee lies in each case with the Provincial Commissioner concerned and the Director of Agriculture. A Committee is gazetted by His Excellency the Governor before it functions.

For general matters of agricultural policy affecting the country as a whole, a Board of Agriculture is under consideration. The composition and constitution of the Board and of District Committees may be found in the Report of the Committee of Agricultural Policy and Organisation. It will be seen that both are thoroughly representative, and that the system provides a framework rigid enough to ensure continuity while remaining flexible enough to allow of free discussion and full consideration of all problems of agricultural development. The system operates under an Ordinance, outlines of which are given in the aforementioned Committee's Report.

This, or some similar system, has been found necessary in most tropical countries. Boards of Agriculture exist in British Guiana, Ceylon, Jamaica, Mauritius, Seychelles, Trinidad and the Windward Islands. The Federated Malay States has an Advisory Committee. In Ceylon a system of District Committees operates under the Board of Agriculture. The division of function which results is of benefit to everyone concerned. The Political Officer is provided with the means of obtaining considered opinion upon all aspects of agricultural policy in his district, the Agricultural Officer is free to perform his correct technical and advisory duties, while unofficial members are kept fully in touch with local agricultural problems and with Government's proposals for solving them.

OUTLINES OF PRESENT POLICY.

The agricultural policy of Government has been summarised in the Annual Address of His Excellency the Governor to Council in February, 1926:—

(1) To protect, improve and develop our staple product, cacao.

(2) To develop new agricultural products of export value and suitable to the soil of the country, and for this to maintain experiment stations, to introduce products of proved local value to the farmers, and to encourage their initiation by private enterprise.

(3) To develop food production.

(4) To advertise our resources and wants by means of shows and exhibitions in those countries where the most valuable results would be obtained, and by placing full information at the disposal of the public in our local Agricultural and Customs Offices and in the Commercial Intelligence Bureau in London.

This summary was expanded by His Excellency in the terms of reference given to the Committee on Agricultural Policy and Organisation, and the Committee's Report gives at length the measures and organisation necessary to give full effect to the policy proposed.

In general, the Committee emphasised the fact that up to the present the investigational work of the Department in the field had suffered severely. Advisory duties, instructional work, and extraneous tasks have been developed at the expense of investigational work, and this, combined with shortage of staff, has brought about a partial bankruptcy of exact and reliable knowledge. Planned investigation is the only means of obtaining reliable knowledge, and this is the first deficiency which should be made good by the Department.

It will perhaps not be out of place here to point out that one of the difficulties met with in the past has been the absence of facilities for training agricultural officers. The question is still a difficult one and has not yet been completely solved. The agricultural officer as a general practitioner or executive officer, in the same sense as the

medical or legal practitioner, is a new arrival in the United Kingdom; in illustration of this it may be mentioned that at the Imperial Agricultural Research Conference held in London last October, not a single officer of this kind was present among the delegates of the United Kingdom or Northern Ireland.

There is no Department of Agriculture in the United Kingdom. Since the Great War, Agricultural Advisers have been appointed in each county, and it is probable that eventually they will have to be linked up into a definite administrative department. But up to the present, the question of an organised and consistent policy for agriculture has not been touched. This has had a direct reflection on the Universities, who until quite lately have turned out specialists in single branches of natural science, and are only now beginning to realise the need for the general agricultural administrative officer. A further effect has been that officers appointed to Departments other than that of Agriculture in the Tropics do not realise the scope of Government's duty with respect to Agriculture, nor understand the functions and work of Departments of Agriculture.

Of course, for some time after the necessary type of officer is obtainable, he will be ignorant of tropical agriculture, and special means will have to be adopted for training him. Eventually, as tropical agricultural science becomes systematised, this handicap will be no more severe than it is in the case of Tropical Medical Officers, but for many years yet some new-comers will be without special tropical knowledge. At present, arrangements exist for training a certain number of them at the Imperial College of Tropical Agriculture, Trinidad, but this has proved to be an expensive, inconvenient and not entirely adequate expedient.

AGRICULTURAL INVESTIGATIONS LOCALLY.

The principal lines of agricultural investigation which are being conducted locally are given below. Necessary explanations concerning the actual or potential importance of each crop or each line of work are given in all cases, and in some cases the probable future developments of the various lines of investigation are indicated.

Examination of Cacao at Ports.

This work began on January 1st, 1927, and since then over 36,000 samples have been analysed, representing more than 106,000 tons of cacao. Five classes of defects were noted, the percentages calculated, and certificates issued to shippers. A confidential report covering the period January to July has been printed, and copies sent to all Political Officers.

In the course of the work several subsidiary problems have arisen, as, for example, the effect, on quality, of wetting by sea-water, the cause of slatey internal colour of the bean, correlation between humidity of the air and hygroscopic moisture of the bean, and the magnitude of the errors normal to the method of sampling

employed. Definite and reliable information is now available on most of these points, and where no confidential figures will be disclosed, papers dealing with the points will appear in the 1927 Yearbook of the Department.

The immediate reason for carrying out this work was the refusal of the American Government to admit defective cacao into their ports. A further reason is that, in normal times, cacao from the Gold Coast is valued at a considerably lower price than the product from efficient plantations. There seems to be little doubt that competition from Nigeria, French West Africa and possibly South America will become increasingly severe, and that defects will be severely penalised. Nigeria and Sierra Leone have already passed Ordinances controlling the quality of exported cacao and other raw products.

The majority of the defects of local cacao have now been proved to be due to inefficient methods of preparation, notably insufficient drying of the bean before bagging. Reaping immature, over-ripe and diseased pods are also important causes of defects. Other causes are insufficient fermentation, and careless admixture of foreign matter. The next and logical step is to make use of this information in order to improve the methods of preparation and the quality of local cacao.

It seems reasonably certain that it is not technical knowledge of the methods of preparation that is lacking in the case of the farmer. What is more necessary is the removal of economic and other factors which cause the farmer to prepare his cacao too hastily and insufficiently. Compulsory legislative measures are not accepted as readily here as in Nigeria and Sierra Leone, and other methods have to be explored. Co-operative fermentaries supervised by the Department of Agriculture, certification of cacao prepared in accordance with accepted standard methods, and the gradual establishment of a scale of differential prices based on quality, are among the lines of work indicated. In certain cases, it may be possible to provide for a system of registered buying centres, and the licensing and registering of buyers, but these and other compulsory measures have to be approached with caution.

Control of Pests and Diseases.

There have been no epidemic outbreaks of diseases or pests of crops in the history of local agriculture. Heavy annual losses occur, however, notably through Phytophthora disease of cacao-pods, and the attacks of the bug known locally as Sankonuabe (Sahlbergella) on the stems of cacao.

A text book of Gold Coast Plant Diseases was published in 1924, and a survey of diseases of local cereals and other grasses is now in press as Bulletin 10. A companion volume on insect pests is needed. The life history of two species of Sahlbergella has been published as Bulletin No. 3, and new parasites of Sahlbergella and Thrips have been discovered and are described in the 1926 Year Book.

The Plant Pests Inspectorate founded in 1925 differs markedly from parallel organisations in other countries. Locally, the work was not advisory; the cost of treatment was at first borne by Government, the work was limited to cacao alone, and surgical measures of treatment were the only ones used. This type of work in other countries is adopted only in cases of sudden epidemic outbreaks on a scale too great to be handled by individual planters.

It is a commonplace of agricultural knowledge that diseases and pests of crops are often the sequels to unfavourable agricultural conditions. Shade, protection from wind, drainage, thorough tillage, conservation of soil moisture, manuring and mulching are neglected by the local farmer, and there is a definite connection between this neglect and the occurrence of diseases and pests. Everything points to the advisability of developing these methods of improving the condition of local cacao, and reserving emergency methods of a more artificial kind for dealing with epidemic outbreaks.

Determinations of Yields of Cacao.

Records of yields are not obtainable from the local farmer, and the information is necessary for several reasons, the chief of which is the urgent task of issuing correct and early forecasts of the cacao crop. The present uncertainty is harmful, leading to frequent fluctuations in price, baseless rumours and panics, and a good deal of misunderstanding.

On each of the major local Experiment Stations a dual series of yields records are kept. The yields of measured areas are carefully recorded, and the yields of individual trees kept. All area yields available to the end of 1925 have been published as Bulletin 4 of the Department, and a series of papers on the individual yields of trees will appear in the 1927 Yearbook. These last form the basis for work directed towards breeding high-yielding strains.

Oil Palms.

It has not been possible in any part of the Tropics to establish a stable industry by capitalising a factory which will subsist solely on raw produce brought from small peasant growers. The oil palm industry is not likely to prove an exception to this general rule. The local farmer has neither reputation nor capital to lose, and a contract between him and a factory is not feasible.

A proposal to establish a block of 1,000 acres of oil palms, to be planted and conducted by the Department of Agriculture, and to form the nucleus of a stable system, is under consideration by Government. Part of the Plantation would be of the improved Deli type used in Sumatra and Malaya. With this as a nucleus it would be possible to support an efficient factory which could supplement its supply by purchasing any extra fruit offered by surrounding farmers.

Careful trials of the effect of cleaning and thinning existing wild groves are being made on a comparatively large scale by the Department at Odumase (Eastern Province), Owan (Central Province), and Anaji (Western Province). Results to date prove that this type of work is expensive and the yields obtained are lower than those obtainable from systematic plantations. Four papers on the oil palm industry were published in the 1926 Yearbook.

Coconuts.

This industry is one of potential value for the coastal areas. Comparative yields of 10 plots of Ceylon palms and 10 plots of local palms, an area totalling about 15 acres, are being published in the 1927 Yearbook.

The Department has established areas totalling 745 acres on the coast, and is now erecting model driers for preparing sound copra. The soundness of this procedure has yet to be proved. The plantations are on leased communal land, and they will revert to the people after Government capital has been recovered. They are valuable centres for experiment, from which reliable information will be obtained, and in addition serve as object lessons to the neighbouring villagers.

Sisal.

The economic position and labour supply of the Accra plains and the dislike the local farmer has to handling this crop, will probably preclude any possibility of sisal becoming a local industry. The plantation and factory work now being carried out by the Department are of a high order of efficiency, reliability and interest, and the trial is on a large scale and thoroughly exhaustive. Several reports have been published on this experiment, and the whole story is now being prepared for press as Bulletin 14.

Limes.

Six hundred acres have been established in the Central Province by farmers, and Messrs. Rose, the lime-juice makers, intend installing a trial factory when the area is in bearing. The market is a limited one, and this industry cannot become a large one in any way comparable with such staples as cacao, coconuts or oil palms. Yields are recorded at Asuansi Experiment Station and were published in the Department's Yearbook, 1926.

Cotton.

The success of cotton in Nigeria and in certain parts of French West Africa has naturally excited interest locally. The information at present available indicates two possible centres in the Gold Coast for careful trial of this industry—Togoland and the Northern Territories. In both these areas the crop has apparently been grown for centuries by the inhabitants, the cultivation being mixed with food crops in Togoland, but single in the Northern Territories.

Past trials by the British Cotton Growing Association, and more recently by the Department of Agriculture, indicate that the local yields have been low. The conditions of climate and soil, however, appear closely parallel to those of the northern Nigerian cotton belt, and further trials are being made with improved types of cotton. The Department in 1927 erected a ginnery at Tamale and will buy all cotton produced by the inhabitants. Transport charges are a factor that has to be considered very carefully.

Cola.

This is a crop of very considerable importance, and one on which no information is available elsewhere. Yield-records are kept at Experiment Stations and some have been published in the 1926 Yearbook. The phenomenon of the occurrence of white and pink seeds on the same tree has been cleared up in 1927. It has been found that a graph of the proportion of white to pink on any one tree is in the form of a symmetrical frequency-curve, the proportion rising from zero to a maximum of about 90 per cent. and then falling to zero in later years. The point is an important one, as white seeds are sold at three to four times the price of pink ones locally.

Other Crops.

The Department of Agriculture is and always has been of opinion that an export industry in grape fruit, oranges, pine apples and bananas, and the production of industrial alcohol are unsuited to the local people and to local conditions. Cane-sugar manufacture is an activity suited only to a capitalist land-owning company, and the same remark applies to Hevea rubber and tobacco. Kapok has possibilities, and the superior type grown in Java is being tried now on the Accra plains by the Department. It seems probable that Shea butter nuts may be made a profitable export product, and records of yields are being taken on an established area in the Northern Territories. A small but promising rice industry exists in the Western Province, and the Department has built and is running a milling-factory for the produce.

Coffee.

This is an industry of potential importance locally, and it seems probable that it might replace cacao in the event of the latter crop ever becoming unprofitable. It is planted readily by farmers, local consumption by Africans is increasing, and consequently the berries sell readily. The product is one of the world's great staples its climatic and soil requirements are similar to those of cacao, and the berry requires even less preparation for the market than does the cacao-bean. The Department of Agriculture gives a bonus of £5 to any farmer who establishes an acre of coffee.

The varieties which have been tested at local Experiment Stations, include Arabica, robusta, *Liberica and stenophylla*. Last year the excelsa type was imported from Java. Records of yields are being compiled and will be published shortly. In general,

Arabica coffee is too delicate a type for local cultivation, and the Liberica bean is too coarse and too low priced. Robusta is the popular, hardy type locally, and the bean is of good quality.

Food Crops.

Very little information is available concerning the comparative yields of different types of local food crops. Yields of maize and cassava were determined on major Experiment Stations in accordance with trials ordered by the Government in connection with consideration of the possibility of making industrial alcohol from starch. These yields will be summarised and published shortly. The collection and comparison of local varieties of beans, peas, yams, potatoes, ground-nuts, guinea-corn, maize, jinjili and other Northern Territory food crops, rice, and cassava, should be undertaken early.

There is very little economic pressure at the present moment on the local peasant, and in general he prefers to grow valuable export crops and to use part of the proceeds for importing food-stuffs. The local prices of indigenous foodstuffs are exorbitant in consequence. Whether the present state of affairs be sound and durable or not, the Department of Agriculture should ascertain the costs of production and yields of local foodstuffs.

OTHER INVESTIGATIONS NEEDED.

Knowledge is lacking on several questions of importance, and these are dealt with in the following paragraphs.

Manures and Manuring.

No manures had ever been imported into the Gold Coast by the Department of Agriculture or by private individuals until 1926, nor had any trials been made locally of systems of manuring. Whatever may be the views held of the length of productive life of the cacao-tree and other perennial crops, there is no doubt as to the fact that yields of any crop can be increased, and profitably increased, by correct use of manures.

An eight-plot series has been now laid down at four major Experiment Stations for comparing the effects of various systems of manuring on cacao. The initial variations between the plots in any one series are very great, greater than can reasonably be expected to result from any ordinary system of manuring. These initial errors are dealt with in a paper appearing in the 1927 Yearbook.

There is some evidence that importation and sale of manures will probably be begun on a considerable scale in the near future. As neither the functions nor the correct use of even the commoner manures are understood by the local farmer, there is need for some measure of control of these imports by Government. The

Committee on Agricultural Policy and Organisation has recommended that an Ordinance be passed providing for control of quality and for the production of analyses of imported manures, the Ordinance to be operated by the Director of Agriculture.

Investigations on Soils.

No information concerning the composition of local soils is available yet. The First West African Agricultural Conference, in March, 1927, adopted provisional standard methods of examination and analysis, and the way is now clear for a satisfactory start.

Ordinary observation shows that there are several types of soil-formations in the country, that many subsidiary problems of soil-treatment are awaiting solution, and that in general full treatment of his soil is rarely practised by the farmer. Observations of this kind must be supported or controverted by exact analyses and figures, and knowledge concerning the characteristics of the principal soil-types is urgently necessary.

Compilation of Agricultural Statistics.

In a country of illiterate small farmers, it is practically impossible to obtain statistics of areas, yields, effects of treatment, incidence and spread of disease and other vitally important agricultural figures. At the same time, it is just in that type of country that these figures are most needed: the Government here is obliged to function in a more paternal fashion in all agricultural matters and to undertake wider responsibilities than are necessary in more developed countries. It must at all times have access to reliable figures of areas and yields of major industries, it must watch the progress of promising new products, and it must know well beforehand the probable output of each industry.

Indirect methods of computing yields and areas will have to be used at first. Estimates by Department Officers, meteorological indications, opinions of chiefs and farmers, and other general indications must be employed. The merchants, in their own interests, must give, willingly and reliably, information concerning stocks, movements of produce, information concerning prices, and the movements of foreign merchants.

The Department of Agriculture is now preparing a memorandum on the compilation of crop forecasts, as a reasoned basis for sound statistical work. They have, in addition, asked for provision of an officer on the staff for statistical work.

Agricultural Instruction.

The term " agricultural instruction " has usually been restricted to mean itinerant, verbal advising of adult farmers. This use has been convenient, in that it has roughly demarcated this type of work from agricultural education in schools and colleges and from special lines of demonstrational work.

Agricultural instruction of this type has been given more than adequate trial. It has been carried on to the partial exclusion of reliable experimental work, of publication of exact information, and of organisation of co-operative work. This statement does not refer to the Gold Coast only, most tropical countries having adopted the system as promising a more speedy dissemination of agricultural knowledge. It tends more and more nowadays to be replaced by specialised lines of organised educational and demonstrational work.

As the result of the experience gained, it is possible to give a series of aphorisms concerning agricultural instructions:—

(*a*) Instruction can be based only on reliable information obtained by rigid experiment.

(*b*) A sound experiment is in itself a demonstration and an effective object-lesson.

(*c*) Itinerant, verbal instruction when necessary, can usually better be given by African than by European officers.

(*d*) An adult farmer is nearly always tied by economic difficulties which prevent him from putting sound advice into practice.

(*e*) The spoken word cannot reach as large a public as can the printed word.

(*f*) Adult instruction cannot replace sound educational work, nor does it usually have as rapid an effect.

It would be puerile to continue attempts to effect by verbal instruction improvement which can only be effected by organised education, by systematic experiment, by economic reorganisation, and by political adjustments. The chief lines of organised work which have been started or are recommended are given below.

Publications.

The Department of Agriculture has now a sound system of publications. Three series are published—popular posters, popular leaflets and technical Bulletins. In addition, a scientific Year-book now replaces the technical sections which used to appear in the Annual Report. These publications, notably the Year-book and Bulletins, are the recognised media whereby reliable information is made public. All Political Officers are supplied with copies as the publications appear.

Proposals have been put forward for taking over the journal of the Agricultural and Commercial Society and converting it into a sound quarterly periodical on tropical agricultural matters. In addition a popular Twi magazine of tropical agriculture has been suggested by the Committee on Policy and Organisation. Finally, the Department is at the present moment planning a standard text-book on Gold Coast agriculture, a book that has long been needed.

Rural Economics and Co-operation.

This is practically an untouched field of work, and at the same time one which will amply repay investigation and systematization. Land tenure problems, transport problems, systems of local marketing, the centralization and improvement of minor village industries, co-operative purchase of manure and other supplies, co-operative preparation of cacao, and financing of small farms are a few of the lines of work indicated.

Proposals are with the Government for adding to the staff of the Department an officer for co-operative work, and for sending him to Ceylon and Madras to study the extensive nature of work of this kind there, and to learn the methods employed. A draft Ordinance controlling Co-operative Societies is now under consideration by Government, and when it is passed, certain local societies will be regularised and registered. Kumasi Training Centre and the four Junior Trade Schools are obvious centres for initiating a system of sound co-operative thrift societies.

School Gardens and Pupils' Home Gardens.

The Education Department has consented to inspection of school gardens by the Department of Agriculture, and the work is beginning during the present quarter. Over 1,000 of the Primary School Teachers in the Colony have attended the annual agricultural courses which have been conducted during the past twenty-three years by the Department of Agriculture, and have taken the examination which follows the courses. These courses have been proved inadequate as means of training, and proposals are now being considered for lessening the number of candidates and greatly lengthening and intensifying their training in agriculture.

Work in the garden and associated work in the school can be most effectively systematized and standardized if a simple handbook of nature study and elementary agriculture were prepared, and such a handbook is being planned by the Department of Agriculture.

Apart from the benefit derived by the children from nature-study lessons and school garden work taught as ordinary, normal parts of the day's lessons, the system reflects beneficially on existing agriculture. Each garden acts as an object lesson to villagers, the children carry novel views and ideas into their homes, and new types of food crops and other plants placed in school gardens by the Department eventually spread to the compounds of the village. Really good school garden work can be done if an ordinary amount of advice, guidance and sympathy is shown to the Teachers, and their keenness stimulated by judicious recognition.

Agricultural Shows.

Shows are a recognised activity locally, and have been organised under the auspices of the Agricultural and Commercial Society for some years past. Undoubtedly a certain amount of good results from them, but certain remediable defects need to be mentioned.

The aims and objects of an agricultural show should be more clearly defined and understood. In origin, shows are really meetings between keenly competitive growers with a view to comparing their products. In other words, the first requirement is keen work, the second requirement is keen competition. The prize is merely the recognition of having won the contest.

This process has been inverted in primitive tropical countries. Prizes are offered by an external authority in order to induce the farmers to bring their products together, in the hope that this will give rise to competitive feeling and so eventually produce more efficient work.

It is clear that, under these conditions, every effort should be made by those responsible for organising a show to give long notice of the event, to excite a spirit of competition beforehand, and to reward those entrants who show proof of having prepared longest and worked hardest towards winning. This is not always observed in local Shows, which too often consist of a mere collection of produce brought together by command, and which neither arise from nor stimulate any spirit of competition.

It is not customary locally to charge an entrance-fee at Shows. While this arrangement is probably necessary in very primitive districts, it is open to some question in more advanced countries. The very fact that it is free raises a question in the villager's mind whether it can be of very much value, and the result is that few exhibits are brought in and few onlookers attend. In general, local Shows are considerably below those of other tropical countries in number of exhibits, quality of exhibits, number of onlookers, and in competitive spirit.

Crop Competitions and Crop Bonuses.

Crop Bonuses have been given locally for coffee only. The system appears to have given fair results, and it is probably an effective though somewhat expensive means of extending a new industry.

Crop Competitions are held annually in most cacao districts of the Colony. The prizes offered are fairly considerable, the number of entrants usually very large, and the spirit of competition is keener than that exhibited in connection with Agricultural Shows. The fact that competing farms are inspected before the actual judging takes place is a point of importance, as competitors are stimulated into making some effort to win the prize. The system might very well be extended to crops other than cacao.

CONCLUSION.

The immense range of subjects which have to be considered by Government in embarking on a policy of agricultural development in a tropical country is only now beginning to be realised. It is only to a very small extent a technical problem, and questions of education, organisation, finance and administration are the chief points now awaiting investigation and settlement. The Political Officer has to play a large part in these matters, and it is not too early to begin now to consider the factors which hamper development in each district of the country, and to plan for their removal. The work will not only be of unusually great importance, but it has the advantage of being more than ordinarily interesting. A series of papers by Political Officers on political factors affecting District agriculture would be welcomed as contributions to the agricultural periodical which it is proposed to found.

PAPER No. V.

AGRICULTURAL SURVEY IN CONNECTION WITH THE PROPOSED NORTHERN TERRITORIES RAILWAY.

By G. C. Coull.

1. This report has been written principally to describe the types of vegetation met with, and the products which grow or are grown at present, and what products are capable of being produced.

2. It is impossible to estimate perennial crops, and in Ashanti there are two types of such products: the indigenous perennial crops as cola, oil palm and funtumia rubber, and the exotic perennials as cocoa and para rubber.

3. The trade statistics do not give any idea to the potential wealth of the country, and it would need an extremely accurate survey of the country to do this.

4. In the Northern Territories shea-butter is the only perennial crop of importance. An estimate of this has already been made, and this product is very widely scattered throughout the Protectorate. (See Sessional Paper VII., 1925-26.)

5. The estimates of annual crops have been entirely based on population.

6. With the advent of a railway there is a possibility of itinerant labourers settling along the line and growing crops for export. If such a thing happened a very great increase could be looked forward to in annual crop production. It is interesting to note that practically the same number of passengers passed Yeji going south as passed going north, namely, 44,265 and 44,209 respectively. Probably the majority of the men going south were itinerant labourers seeking work, and I should say that coming north there was an equivalent number returning from work.

7. From the census reports it would appear that the population in the Northern Territories is increasing slightly, but at what rate it is impossible to say.

LOCATION.

8. There are two routes proposed which will be described as the Eastern route and the Western route.

9. The Eastern route runs approximately—

Kumasi — Offinsu — Aboifur — Sekodumase — Abease — Akamadei — Tammle — Nasia — Naga — Santejan — Walembele — Daffina.

10. The Western route runs approximately—

Kumasi — Nkwanta — Sunyani — Tainsu — Bamboi — Bole Wa — Daffiana — Walembele — Santejan — Naga.

PHYSICAL FEATURES.

11. From Kumasi north by both routes every type of vegetation is met with, from the deciduous forest to savannah.

12. Generally, the deciduous forest runs from Kumasi to the Ashanti—Northern Territories boundary, then in the Northern Territories tree savannah is met with which gradually merges into savannah.

13. From a short distance North of Sekodumase on the East and Sunyani on the West, a certain amount of fringing forest is met with which stretches to the River Volta. This fringing forest is also met with along river banks and in hollows.

AGRICULTURAL PRODUCTS.

14. The agricultural products, which may be looked forward to for export, are—

Cacao	*Theobroma cacao.*
Kolanut	*Cola Acuminata.*
Rubber (indigenous)	*Funtumia Elastica.*
Rubber (exotic)	*Hevea brasiliensis.*
Palm oil	*Elaeis guineensis.*
Groundnuts	*Arachis Hypogea.*
Cotton	*Gossypium spp.*
Shea kernels	*Butyrospermum parkii.*
Benni seed	*Sesamum indicum.*
Bungu seed	*Ceratothceca sesamoides.*
Neri seed	*Citrullus vulgaris.*
Kapok	*Eriodendron orientale.*
Fibre	*Agave Sisalana.*
Fibre	*Hibiscus spp.*

POPULATION.

15. The populations, district by district, through which the two routes run, and twenty-five miles on either side of them, is as follows—

KUMASI	27,000	KUMASI	20,000
MAMPONG	Nil.	SUNYANI	15,000
EAST GONJA	6,000	WENCHI	18,000
WEST DAGOMBA	71,000	KINTAMPO	7,000
SOUTH MAMPRUSI	6,000	BOLE	7,000
NORTH MAMPRUSI	150,000	WA	40,000
LAWRA-TUMU	40,000	LAWRA-TUMU	40,000
WA	40,000	NORTH MAMPRUSI	150,000
TOTAL	340,500	TOTAL	297,500

16. Both routes run through districts where there are large towns, and, in these towns many of the inhabitants are traders, itinerant labourers, and foreigners, and therefore unproductive as regards agricultural products. An estimate of 20,500 as such inhabitants on the Eastern route, and 17,500 on the Western route,

has been made. These allowances are necessary when estimating the amount of any crop capable of being grown by the native population.

ESTIMATE OF PRODUCTS.

17. The estimates of crops have been based entirely on population.

18. In dealing with perennial crops it is extremely difficult to make estimations, as one man can keep on increasing his plantation, and he can obtain itinerant labourers to harvest his crop.

19. The estimate of the output of annual crops is entirely dependent on population, and for this purpose the adult male population has been taken as one-ninth of the whole, and the female population as one-seventh of the whole.

20. For purposes of an export an estimate has been given of what one man or one woman can do in addition to the normal work of providing food for themselves. In a country such as the Northern Territories, when dealing with production, it must never be forgotten that the Protectorate is faced with the problem of an annual drought of five months. During the remaining seven months the food supplies of the year have to be raised, and the law of self-preservation naturally makes this of primary importance.

21. The difficulty caused by the present lack of population would solve itself, as it was found there was a ready market for the produce, and so people would be induced to settle from other districts.

22. There is a certain amount of overlapping of products in the various zones of vegetation; the table below shows these zones and their main agricultural products—

Deciduous Forest ..	Cacao, rubber, cola, and oil palm.
Fringing Forest ..	Groundnuts and cotton slightly.
Tree savannah and savannah.	Groundnuts, cotton, shea-kernels, benni seed, bungu seed, neri seed, kapok and fibres.

23. Generally speaking the perennial crops would be produced in Ashanti, with the exception of shea-kernels and kapok, and the annual crops in the Northern Territories, with the addition of shea-kernels and kapok.

24. Each crop will now be discussed by itself.

Cacao.

25. With a perennial crop like this, any exact estimate is impossible, as the farmer can go on increasing his plantation from year to year, and can obtain itinerant labourers to harvest the crop. This is the state of affairs at present in the deciduous forest.

26. It is estimated that 10,000 tons was produced along the Eastern route and 15,000 tons along the Western route, 7,000 tons of this being produced round Sunyani.

Rubber.

27. At present there is practically no tapping, though both routes pass areas of great potential output. The funtumia elastica is indigenous, and there are many trees at present capable of being tapped. Were a market created and a fair price offered, there might be a large export again. Para rubber, though not indigenous, also grows well.

Cola.

28. This crop is indigenous to Ashanti, and both routes pass through large areas of potential supply. This crop is peculiar in so far as the owners of the trees take practically no interest in them.

The method of collecting the crop is as follows:—

Moshis from the North and Lagosians from Nigeria arrive at the beginning of the season and settle down in villages, and remain there till the season is finished, collecting and picking the product. The traders get permission from the owners of the trees to collect the crop, and pay so much per hundred cola-nuts. The trees receive no attention except a periodic circle-weeding, which is done mainly to assist the collection of the ripe fruits as they fall on the ground.

29. It is extremely difficult to find the potential output of this product, but certain figures are available for the present trade. The following table shows the present trade:—

From Kumasi South	10,000 tons by rail.
To North by Western route ..	1,067 tons by headload.
To North by Eastern route	546 tons by headload.
	154 tons by lorry.

30. With a railway running North on either route the up-trade would probably increase greatly, and I should estimate 14,000 tons would be transported.

Oil Palm.

31. There are many areas in the deciduous forest where the oil palm grows abundantly. At present there is no industry. The oil is used locally for soap-making, and the trees are cut down to supply palm wine.

Groundnuts.

32. In the deciduous forest the crop is not grown; it is more common in the fringing forest; in the Northern Territories it is grown universally.

33. The crop is easily cultivated, gives a quick return, is well known to all farmers in the savannah country, and seems one for which there is a future, in the event of cheaper transport.

34. The production of groundnuts is entirely dependent upon the population, and, for purposes of estimating the probable

export, it is estimated that each adult male is capable of producing a crop from one acre yielding 800 lbs., in addition to his ordinary farming. The yield from the savannah country would be:—

	Males.	Groundnuts. tons.
Eastern route	33,666	12,023
Western route	26,389	9,424

35. This merely represents the yield for within twenty-five miles of the railway, and it is considered that, if a market were created, it would be grown in many places served by motor roads and a great increase could be looked forward to.

Cotton.

36. This crop is not grown South of Nkoranza or Kintampo, and very little in the fringing forest: again the Northern Territories seem to be where the export would come from.

37. It is grown through the Protectorate in small quantities for local consumption, and the planting, cultivating and harvesting of the crop is well known to the inhabitants.

38. At present the establishment of this crop for export is engaging the attention of the Department of Agriculture in the Northern Territories, and a great increase in the amount grown is looked forward to. This seems a crop for which there is a future. A cotton ginnery has been erected at Tamale.

39. If each man grew 200 lbs. of seed cotton per annum, the yield would be:

	Population.	Seed cotton. Tons.	Lint cotton. Tons.
Eastern route ..	33,666	3,000	1,000
Western route ..	36,389	2,327	775

Shea-kernels.

40. The shea tree is widely distributed through the Northern Territories, and the amount capable of collection is again dependent on the population.

41. With the advent of the motor road to Tamale the export of shea-butter South is increasing yearly, and in markets near the motor roads it is becoming more common to see shea-kernels, brought in from villages farther afield, purchased by women who extract the butter and sell to traders going South.

42. Last year one commercial firm started buying shea-kernels for export, and they have again started buying this year.

43. The collection of this crop is entirely in the hands of the women, and if only age-long customs could be broken down and the men induced to collect the kernels and sell them, there would be a great increase in the amount that could be collected.

44. The calculated amount capable of being collected by the women is:—

	Population.	Kernels.
	Women.	Tons.
Eastern route	43,286	10,821
Western route	33,928	8,482

This is based on the fact that one woman could collect 5 cwts. of kernels in one season of three months.

Benni Seed (Gingelly).

45. This crop is known and grown in many parts of the Northern Territories, and could be grown on a large scale were the demand created. The oil expressed from the seed is a valuable one which has the property of keeping for a very long period without going rancid. The probable amount might be:—

Eastern route	100 tons.
Western route	80 tons.

Neri Seed.

46. This seed has been valued in England at £17 to £18 per ton, and is grown throughout the Northern Territories and Northern Ashanti.

47. If every woman grew enough to produce 20 lbs. the yield would be:—

	Population.	Neri Seed.
	Women.	Tons.
Eastern route	43,286	390
Western route	34,928	312

Kapok.

48. This is seen principally in the Northern Territories. In the deciduous forest the trees are of such a size that the collection of the floss is entirely dependent on what falls from the trees. It is impossible to state the probable quantity for export, but it is a product which could easily be grown on a large scale.

Fibres.

49. Sisal grows well but is not grown by the natives. The native fibre is a product of two species of hibiscus. The hibiscus fibre has been valued in Liverpool as worth £18 to £19 per ton, with Calcutta jute at £22. It is impossible to state the probable yield, but it could probably be developed were a market created.

Food Crops.

50. It must not be forgotten that there would be a large amount of food crops for the South. The present export of groundnuts, guineacorn, millet and yam is increasing rapidly and is carried to Kumasi by motor lorries.

Summary.

51. The following table summarises the population on the two routes available for producing the crops:—

Population.	Eastern.	Western.
Total	340,500	297,500
Adult males	37,833	33,055
Adult females	48,642	42,500
Adult males for groundnuts, cotton	33,666	26,389
Adult females for shea-butter	43,286	33,928
Adult females for neri seed	43,286	33,928

52. The above table consists merely in the population within twenty-five miles each side of the proposed railway routes; and the production of crops would probably be carried out by many more were a market created.

53. The following table summarises the products capable of being produced along the proposed routes:—

Product.	Eastern.	Western.
	Tons.	Tons.
Cacao	10,000	15,000
Cola	14,000	14,000
Rubber	?	?
Palm oil	?	?
Groundnuts	12,023	9,424
Cotton (lint)	1,000	775
Shea-kernels	10,821	3,482
Benni seed	1,000	80
Bungu seed	?	?
Neri seed	390	312
Kapok	20	15
Fibres	?	?
Totals	48,354	48,088

CONCLUSION.

54. In the Northern Territories, speaking generally, the lack of interest shown by the population in growing crops for money seems to be because once having the money there is nothing to spend it on. With the advent of a railway the inevitable result would be the establishment of stores, and, with the right kind of goods which appeal to the native, it would act as an incentive to him to grow crops, as, by this means alone, is he able to obtain money beyond what is necessary for him to live.

55. The figures I have given in paragraph 51 and 53 are merely for strips of territory alongside the proposed routes, and when dealing with probable increase in products the question of population is of paramount importance. The Eastern route certainly taps a greater population on either side of it in the Northern Territories. The Western route has a large expanse of uninhabited country from Kintampo nearly to Wa, and the British population to the West is very scant.

56. With the advent of cheap transport there seems no doubt that an export of products from the Northern Territories could be established.

PAPER No. VI

DETERMINATION OF THE ACCURACY OF CERTAIN METHODS OF SAMPLING CACAO-BEANS.

By A. B. Culham and J. L. Scott.

Since the inauguration of Cacao sampling in January, 1927, a systematic analysis has been carried out on practically all shipments leaving this country. By this means it is hoped to obtain an accurate survey of the various defects, and to ascertain which of these predominate. It will be seen whether they are due to the physical conditions of the country, to the cultural methods and the varieties grown, or, to faulty preparation of the bean by the farmer. We already know the causes of the various defects. When we know their proportions it will be possible to take steps to remove the conditions which give them their being.

AMERICAN FOOD AND DRUGS ACT.

An impetus was given to the need for sampling by the American Government's refusal to allow the importation of cacao below a certain standard of purity. Since the passing of a law disallowing entry to cacao containing 10 per cent. mouldy beans or 15 per cent. mouldy and weevilly beans, a certain proportion of our produce exported to New York has been condemned. In view of that very liberal standard, this failure shows the very bad condition of our cacao. In addition to the loss of money involved there has been a consequent loss of prestige to the Gold Coast as a cacao-producing country. The matter becomes one for serious consideration when it is remembered that the supply of cacao is steadily approaching the demand and that legislation of a severer type may yet be introduced.

POSITION OF THE EXPORTER.

The exporter is faced with a possible condemnation of his exports, with the resulting trouble and loss of money. While our main object, in instituting such a scheme, was the desire to obtain scientific details for our own use, we had to remember the primary necessity of the exporter. It will therefore be seen that if our sampling was to be of any value to the exporter it had to conform very much to that at present adopted in New York. For

this reason our present methods, except for the actual analysis of the beans, are similar to those used by the American Department of Agriculture. It is our purpose to give some demonstrations of these methods and of the extent to which they are accurate.

THE SAMPLER.

The cacao for analysis is extracted by means of a sampler. This instrument is made of brass, 15 inches in length and conical in shape. One end is a circle 2 ins. in diameter, while the other is sharp point. The inside is hollow and on one side there are three apertures, each large enough to admit cacao beans, *i.e.*, $2\frac{1}{1}$ ins. long and $\frac{1}{2}$ in. wide. A diagram is given in Plate II.

The sampler is inserted into a place mid-way up the side, at right angles to the bag. It is pushed in until "A" touches the circumference and " B " reaches the centre of the bag. By a backward and forward movement a conical section of beans is removed from the bag, as illustrated below. On removal of the sampler the hole made by its insertion is closed by replacing the displaced strands with the point of that instrument. Labourers become so expert in the process that it is often difficult to detect where the bag has been puncured.

SERIES A.

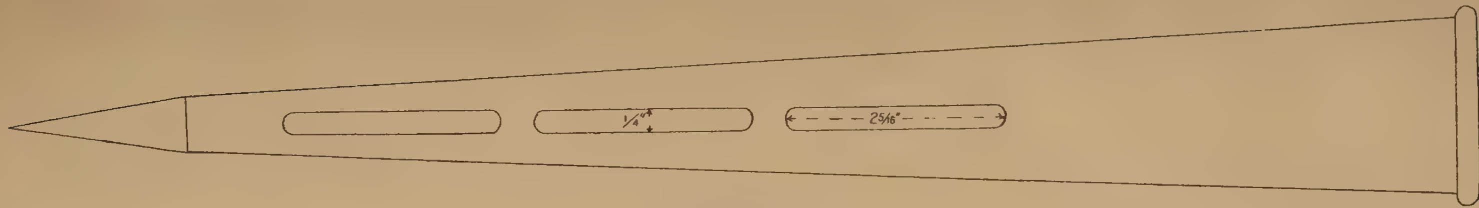
ACCURACY OF SAMPLER.

An experiment was carried out with the object of determining the accuracy of the results obtained by the sampler. It also aimed at finding to what extent the reading of one insertion could be expected to give a picture of the cacao in the bag. No instrument can be expected to give accurate results when the contents of a bag are uneven in quality. The experiment was therefore carried out on cacao of even distribution. The conditions were made similar to those obtaining on the beach at Accra.

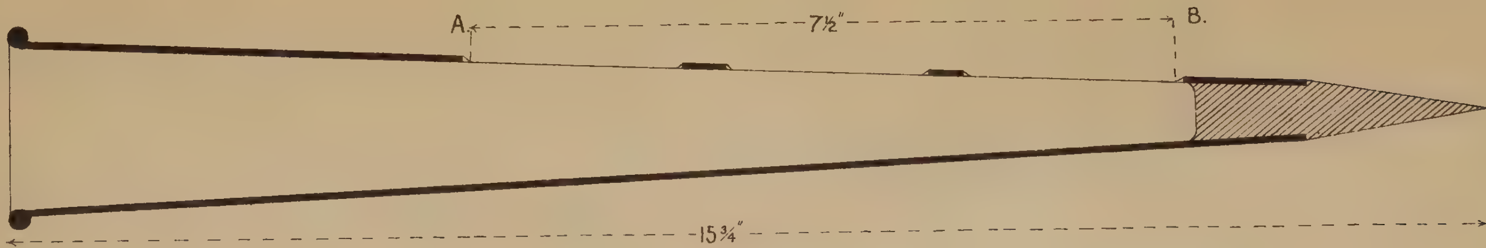
A quantity of 100 lbs. of cacao was taken, 5 lbs. drawn therefrom, stained blue, mixed with the remaining 95 lbs. and the whole put into a bag of the usual type. The mixing was made as thorough as possible, but, of course, it could not be perfect. The sack was sampled in the manner already described, a count made of 100 beans from the contents, and the percentage of stained beans duly noted. A series of such tests was carried out, care being taken, after each test, to remove the contents from the bag and thoroughly remix, after adding those beans removed in the previous test. $\sqrt{N}$ tests were thus made equivalent to the examination of $\sqrt{N}$ bags of known standard and reasonably equal distribution of quality. Samples were taken until an average was obtained which gave a negligible error in the percentage of stained beans. Similar experiments were carried out on equal quantities of cacao containing 10, 15, 20, 25 and 30 per cent. stained beans. The figures are given in tabulated form.

PLATE II.

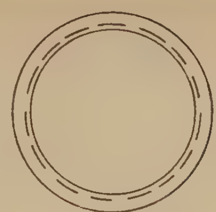
SAMPLER FOR CACAO BEANS



ELEVATION



SECTION



PLAN

Scale: 6 Inches – 1 Foot.

Reproduced at Survey H.Q. Accra, 1928.

Test No.	Exp. No. 1. 5% stained beans.	Exp. No. 2. 10% stained beans.	Exp. No. 3. 15% stained beans.	Exp. No. 4. 20% stained beans.	Exp. No. 5. 25% stained beans.	Exp. No. 6. 30% stained beans.
1	5	15	8	26	28	29
2	6	13	12	16	21	31
3	4	10	13	18	30	30
4	4	9	20	18	35	28
5	4	6	9	26	34	28
6	1	10	14	18	25	29
7	7	14	18	16	24	30
8	5	12	9	28	23	30
9	5	12	11	20	16	49
10	5	10	13	17	27	32
11	6	11	6	26	23	29
12	5	12	15	19	22	24
13	4	6	12	22	23	34
14	5	19	13	23	28	30
15	8	10	21	14	29	27
16	5	10	7	25	33	28
17	5	10	20	23	23	33
18	3	9	16	19	23	33
19	5	11	26	15	24	21
20	8	5	12	20	22	33
Total	100	214	275	409	513	608
Average ..	5%	10·7%	13·75%	20·5%	25·7%	30·4%

The errors of averages were taken after 5, 10, 15 and 20 tests. The results are tabulated below:—

Errors of Averages after tests.	Exp. No. 1.	Exp. No. 2.	Exp. No. 3.	Exp. No. 4.	Exp. No. 5.	Exp. No. 6.
5 tests ..	·7%	·3%	2·8%	·4%	4·6%	·8%
10 ,,	·4%	1·1%	2·5%	·4%	2·2%	1·6%
15 ,, ..	·1%	·2%	2·1%	·4%	·6%	·6%
20 ,, ..	·0%	·7%	1·35%	·05%	·6%	·4%

A perusal of these tables gives the following facts:—

1. Even in cacao of good distribution there are variations between individual samples.
2. No one sample can be depended on to give an accurate description of the contents of a bag.
3. A certain number of samples must be taken before an average of accurate standard can be obtained. Twenty would seem to be that figure. Ten is certainly too small.
4. The variations off-set one another. As only the averages are used in sampling, the sampler seems to be perfectly satisfactory. The accuracy after 20 samples is remarkable.
5. When less than twenty samples are used there is an error. This error is not great, however; moreover, a perusal of

the grading figures will show that less than 2 per cent. of the cacao sampled was in shipments requiring fewer than 20 samples.

Series B.

THE RELATIVE MERITS OF DIFFERENT METHODS OF SAMPLING.

These experiments were carried out in order to determine whether the present method of obtaining samples was better than or inferior to other methods. Using 100 lbs. of cacao containing 15 per cent. stained beans, the following methods of sampling were used: —

1. Sampler at top end of side of bag.
2. Sampler at middle end of side of bag.
3. Sampler at bottom end of side of bag.
4. Sampler thrust perpendicularly into mouth of open bag.
5. Handful of beans from centre of exposed surface in open bag.
6. Handfull of beans from centre of bag with mouth open.
7. Handful of beans from side of exposed surface of open bag.
8. Handful of beans from hole at top end of side of bag.
9. Handful of beans from hole at centre of side of bag.
10. Handful of beans from hole at bottom of side of bag.
11. Handful of beans from bulked cacao on ground.

The results of these experiments are tabulated below: —

Test No.	Exp. No. 1.	Exp. No. 2.	Exp. No. 3.	Exp. No. 4.	Exp. No. 5.	Exp. No. 6.	Exp. No. 7.	Exp. No. 8.	Exp. No. 9.	Exp. No. 10.	Exp. No. 11.
1	9	16	24	8	17	17	21	21	9	19	14
2	8	14	14	17	23	15	13	10	9	17	19
3	15	18	13	18	15	14	16	10	19	15	10
4	17	16	13	9	25	14	17	13	15	21	14
5	17	18	16	13	18	19	20	7	15	10	11
6	8	6	10	9	17	17	17	15	15	22	21
7	15	12	17	12	16	14	13	10	11	21	11
8	14	14	20	7	17	14	16	7	8	21	10
9	15	15	17	17	15	12	19	9	14	17	20
10	16	12	11	12	18	15	22	13	13	18	9
11	20	17	16	7	12	14	18	18	12	18	16
12	8	13	8	12	17	11	14	13	15	14	13
13	15	16	17	18	16	12	19	10	14	12	12
14	19	8	14	13	20	17	12	22	16	8	19
15	19	15	13	12	11	19	16	15	16	20	19
16	15	12	19	18	19	10	20	15	18	18	14
17	13	20	9	11	11	11	11	16	18	12	14
18	16	17	18	17	13	14	17	12	10	20	13
19	24	19	17	9	10	16	15	16	15	20	15
20	14	11	19	12	13	14	14	13	13	11	16
Total	297	289	305	251	323	289	330	265	275	329	290
Average	14·85	14·5	15·25	12·6	16·15	14·45	16·5	13·3	13·75	16·45	14·5

The large variations between different samples is again demonstrated. The importance of having a certain number of tests before taking an average is shown by the following errors of averages:—

Error of Aver. after	Exp. No. 1.	Exp. No. 2.	Exp. No. 3.	Exp. No. 4.	Exp. No. 5.	Exp. No. 6.	Exp. No. 7.	Exp. No. 8.	Exp. No. 9.	Exp. No. 10.	Exp. No. 11.
5 tests	1·8	·6	1·0	2	4·6	·8	2·4	2·8	1·6	1·4	1·4
10 ,,	1·6	1·3	·5	2·8	2·1	·1	2·4	3·5	2·2	3·1	1·1
15 ,,	·7	1·3	·1	2·7	1·5	·1	1·9	2·1	1·6	1·5	·5
20 ,,	·15	·5	·25	2·4	1·15	·55	1·5	1·7	1·2	1·5	·5

A comparison of these errors indicated the following:—

1. All methods gave reasonably accurate results.
2. Four methods gave more accurate results than any of the others.

   They are:—

   (*a*) Insertion of sampler into side of each at top end.
   (*b*) Insertion of sampler into side of each at middle.
   (*c*) Insertion of sampler into side of each at bottom end.
   (*d*) Selections from cacao bulked on floor.
3. In all cases there is a decrease in error of average in proportion to number of samples taken.
4. Insertion of sampler down centre of open bag is the least satisfactory.

It therefore seems that our present methods of obtaining samples are, in addition to being the only apparent and practical ones, the most accurate.

Series C.

METHOD OF EXAMINATION OF A CONSIGNMENT OF CACAO.

Our present methods of examination are based on the mathematical fact that in random sampling, the square root of the number of variations in any collection of figures gives an average which is reasonably approximate to that of the whole. That is to say, in a consignment of cacao containing 400 bags, it will be reasonable to expect a fair picture of the contents from an examination of 20 bags. It must be remembered, of course, that the random selection must be done intelligently and that the 20 bags must be as fairly distributed as possible before a reasonable result can be expected. By this means, not only will an average equal to that of the total be obtained, but the various samples will indicate whether the bags in the consignment are of even quality. It is of the utmost importance to the cacao buyer that not only must his

cacao be of good general quality, but also that it be of even standard. It has therefore been our aim to have sufficient samples to give an exact picture of the quality and at the same time reflect the degree of uniformity. At the same time it has also been necessary to remember that there must be a minimum of cacao removed from shipments, and a minimum of interference with movements of exporters. For these reasons the Department would require very definite knowledge of the inadequacy of the square root method before adopting one in which a greater number of samples would be required.

EXAMINATION OF THE ACCURACY OF THE METHODS.

A series of experiments were undertaken with a view to determining the errors to which this system is liable. The primary aim was to find if the examination of the square root of the number of bags in a consignment gave a reasonable picture of the whole. Such an object can only be achieved in one way, and that is by an actual examination of all the bags in a consignment, taking the average and comparing it with that of the square root taken from the assembled figures.

Such a detailed examination is obviously not practicable. The rapidity of movement of the export trade does not allow time to the limited staff on experimental work, and the amount of cacao removed from a consignment would be considerable. Other methods had therefore to be adopted which were more in keeping with the means at our disposal. One scheme suggested itself which seemed at once practicable and at the same time similar in idea to the one already mentioned.

The figures collected from various ports since January, 1927, contain enough samples to form many consignments. The monthly figures from any port are sufficient to represent a shipment of sufficient size to test the $\sqrt{N}$ method; in addition, having been taken from many different sources, they present a consignment of such extreme variation in quality as to offer a very exacting test of our methods of examination. A detailed description of these experiments and the conclusions drawn therefrom will now be given.

Experiment No. I.

This experiment was carried out to determine whether the square root method would be accurate in a consignment containing large variations of quality. It also aimed at finding whether the method of choosing the bags for inclusion in the square root was likely to affect the accuracy of the result.

The Accra grading reports were therefore examined and those shipments were chosen the samples from which had shown large variations in quality during grading and which at the same time differed markedly in quality from one another. These were totalled together and the average of the whole taken. The results are given below ;—

Serial No.	No. of samples of 100 beans.	Total number of beans showing				
		*M.	G.	S.	W.	D.
123	100	289	400	1,384	320	420
155	83	289	362	449	102	239
157	70	323	504	439	225	98
139	67	335	345	373	110	59
192	63	27	91	125	1	79
193	17	16	29	65	7	19
Total ..	400	1,279	1,731	2,835	695	914
Average ..	—	3·2	4·3	7·1	1·7	2·3

Serial No.	No. of samples of 100 beans.	Liverpool requirements.			
		*S.	O.D.	Good.	Total.
123	100	1,384	1,103	7,513	10,000
155	83	449	850	7,001	8,300
157	70	439	984	5,577	7,000
139	67	373	687	5,640	6,700
192	63	125	191	5,984	6,300
193	17	65	68	1,567	1,700
Total ..	400	2,835	3,883	33,282	40,000
Average ..	3·2	7·1	9·7	83·2	—

*M = Mouldy. S = Slaty. D = Defective.
G = Germinated. W = Weevily. O.D = Other Defects.

Different methods of taking the square root were followed.

Method 1. *By choosing the* 20 *samples from six shipments in proportion to the relative number of samples in each shipment.*

Thus we had from

Shipment	No.	123,	containing	100	bags,	5	samples.
,,	,,	155	,,	83	,,	4	,,
,,	,,	157	,,	70	,,	3	,,
,,	,,	139	,,	67	,,	3	,,
,,	,,	192	,,	63	,,	3	,,
,,	,,	193	,,	17	,,	2	,,

As far as possible the samples were chosen at equal intervals over each shipment. The individual samples were found to vary much. The percentage good in each will indicate the extent of this variation:—54, 76, 90, 79, 88, 65, 89, 91, 74, 81, 78, 86,

85, 97, 92, 96, 95, 93. The average worked out to be 84·4, thus giving an error of 1·2 per cent. This, to all intents and purposes, is negligible.

Method 2. *Random.* The 400 samples contained in the consignment were each written down on separate slips of paper. These were mixed up and then placed in groups of five along a table in order to resemble the array of bags on the wharf. Twenty samples were taken therefrom without making any regular distribution, all of them being drawn from the first 20 groups. The following results were obtained:—70, 80, 61, 78, 93, 69, 78, 46, 85, 96, 69, 49, 74, 82, 97, 92, 67, 77, 71, 95. The average worked out at 76·4. An error of 6·8 per cent, was therefore made, showing that in this case the method was not accurate.

Method 3. *Experiment No. 2 was repeated, but in this case the samples were drawn from the first* 40 *groups;* an average of 90 per cent. was obtained showing an error of 6·8 per cent. Again, the result was very unsatisfactory.

Method 4. *The selection was spread equally over the entire number of groups, i.e.*, one sample was selected from every four groups. This was repeated eight times, so that 160 determinations in all resulted. The averages are tabulated below:—

Repetition No.	Means of each group of twenty determinations.				
	M.	G.	S.	W.	D.
1	3·2	5·3	6·9	2·1	2·6
2	2·9	3·7	7·3	9·0	1·9
3	3·3	5·2	6·1	2·2	1·2
4	1·2	3·9	4·3	·4	1·3
5	2·4	3·6	5·7	·9	2·6
6	3·4	6·5	8·1	1·8	2·2
7	2·0	5·8	19·9	·1	3·7
8	2·5	3·7	7·4	·9	2·8
Mean of original 400 samples.	3·2	4·3	7·1	1·7	2·3

Repetition No.	Summary of Liverpool Standard.			
	S.	O.D.	Good.	Total.
1	6·2	11·5	81·6	100·0
2	7·3	7·7	85·0	,,
3	6·1	9·6	84·3	,,
4	5·8	6·6	87·6	,,
5	5·7	8·1	86·2	,,
6	7·8	11·3	81·0	,,
7	11·5	10·4	78·1	,,
8	7·4	8·7	83·9	,,
Mean of original 400 samples.	7·1	9·7	83·2	

The percentage good shows errors of 1·6 per cent., 1·8 per cent., 1·1 per cent., 4·4 per cent., 3·0 per cent., 1·8 per cent., 5·1 per cent., 0·7 per cent. This shows that even with careful selection of samples errors varying from 1 per cent. to 5 per cent, are possible. In four tests, the error was less than 2 per cent, and in six cases less than 3 per cent.

As each 20 samples were taken they were not replaced, so that from the figures given above, $^2\sqrt{N}$, $^3\sqrt{N}$, etc., can be calculated. By taking $^2\sqrt{N}$, the error is reduced very much.

As has been already pointed out, the consignment selected was an extreme case of mixed quality. Up to this point the experiments made cannot be regarded as entirely conclusive, and were more in the nature of tentative efforts at finding methods of testing. Certain very definite conclusions can nevertheless be drawn. They are:—

1. The selections must be carefully made. The officer sampling cacao cannot expect accuracy by taking all his samples from one part of a consignment. The sampling must be made as representative of the whole as possible. When the consignment is mixed an error must be expected, no matter how careful the selection may be.

Further experiments were carried out along the lines indicated above.

SUBSEQUENT EXPERIMENTS IN SQUARE ROOT METHODS.

Experiment No. II.

A similar experiment was carried out, using the monthly collection of figures from one port to represent a consignment. At the present time these figures are very even throughout the month. In this case the monthly report from Winneba for the month of October was chosen. Since the individual variations were very small, an accurate result was to be expected from the square root method.

The serial numbers included in the consignment were 51-63, inclusive. The total of the samples in each serial was taken, the analytical figures added together, and the average taken by

dividing the total number of samples. The results are tabulated below:—

Serial No.	No. of samples of 100 beans.	Number of beans showing.				
		M.	G.	S.	W.	D.
51	40	31	104	122	7	63
52	80	97	242	343	26	143
53	35	45	100	132	10	59
54	11	10	30	56	2	16
55	39	73	80	64	75	64
56	29	10	60	166	0	28
57	49	57	198	105	68	89
58	29	19	13	50	0	36
59	28	12	19	74	1	20
60	57	92	80	112	0	129
61	57	80	90	176	2	144
62	49	49	52	118	0	114
63	29	39	20	104	1	46
Total ..	532	614	1,088	1,622	192	852
Average ..	—	1·2	2·0	3·0	·4	1·6

Serial No.	No. of samples of 100 beans.	Summary in accordance with Liverpool requirements.		
		S.	O.D.	Good.
51	40	122	192	3,686
52	80	343	487	7,170
53	35	132	208	3,160
54	11	56	56	988
55	39	64	277	3,559
56	29	166	100	2,634
57	49	105	376	4,419
58	29	50	68	2,782
59	28	74	47	2,679
60	57	112	284	5,304
61	57	176	303	5,221
62	49	118	207	4,575
63	29	104	104	2,692
Total ..	532	1,622	2,709	48,869
Average ..	—	3·0	5·1	91·9

As in the previous experiment, the analysis of each sample was written down on a slip of paper. The 532 pieces were mixed together and then ranged out on a table in groups of five. The square root of the number of samples was taken ten different times,

care being taken to make each distribution as representative as possible, *e.g.*, a slip of paper was taken from the top of group 1, 6, 11, 17, etc. Different groups were used at each test. The results are tabulated below:—

No.	M.	G.	S.	W.	D.
1	1·6	2·2	3·0	·3	2·1
2	1·2	2·1	2·8	·5	1·3
3	1·3	1·9	2·4	·4	1·7
4	1·3	1·6	1·6	—	2·0
5	·8	1·9	2·5	·1	2·3
6	·8	1·8	3·2	·5	2·5
7	1·5	2·1	3·3	·5	1·7
8	1·3	2·0	2·3	·04	1·3
9	1·1	2·0	3·2	·9	1·7
10	1·1	2·0	2·9	·2	1·4
Means of original 532 samples.	1·2	2·0	3·0	·4	1·6

No.	S.	O.D.	Good.
1	2·9	5·9	91·2
2	2·8	4·9	92·2
3	2·4	5·1	92·4
4	3·7	4·7	91·6
5	2·5	4·9	92·6
6	3·2	5·5	91·3
7	3·3	5·5	91·2
8	2·3	4·4	93·3
9	3·2	5·4	91·4
10	2·9	4·5	92·6
Means of original 532 samples.	2·0	5·1	91·9

The results obtained in this experiment are remarkably accurate. The errors of the average of good beans are 0·7 per cent., 0·3 per cent., 0·5 per cent., 0·3 per cent., 0·7 per cent., 0·6 per cent., 1·4 per cent., 0·5 per cent., 0·7 per cent. Only in one test out of the ten was there an error of more than 1 per cent. This proves conclusively that at the present moment the results from all shipping ports are very accurate.

Experiment No. III.

The cacao exported from Sekondi is indicated as being of a very mixed character. The grading report for the month of August, 1927, is easily the worst that has come to this office since

the cacao sampling was started. In addition to the fact that the average for the whole is 58·1 per cent. good, the individual samples vary to an enormous extent. The best sample is 95 per cent. good while the worst is 4 per cent. good. These collected samples present a consignment of as varied a type as it is possible to obtain, and certainly one which appears to be a very severe test of the square root method of examining a consignment. These figures were, therefore, treated in the same way as the Winneba figures were treated in Experiment No. 5. The report includes serials 110-120 inclusive. These were totalled together as in the table below:—

No.	No. of Samples.	M.	G.	S.	W.	D.
110	77	934	485	1,486	186	1,047
111	63	804	386	693	199	613
112	29	283	238	164	95	300
113	19	197	115	169	73	143
114	57	608	372	311	83	351
115	28	316	211	141	89	226
116	45	2,321	994	470	294	561
117	116	2,135	614	600	468	437
118	90	164	127	194	89	229
119	22	222	178	290	74	311
120	25	775	384	286	163	233
Total ..	571	8,759	4,104	4,804	1,813	4,451
Average ..	—	15·3	7·2	8·4	3·2	7·8

No.	No. of Samples.	S.	O.D.	Good.
110	77	1,486	2,652	3,562
111	63	693	2.002	3,605
112	29	164	916	1,820
113	19	169	528	1,203
114	57	311	1,414	3,975
115	28	141	842	1,817
116	45	470	4,170	6,960
117	116	600	3,654	4,746
118	90	194	609	1,397
119	22	290	785	1,425
120	25	286	1,555	2,659
Total	571	3,804	19,127	33,169
Average ..	—	8·4	33·5	58·1

The individual slips were again written on pieces of paper, which were mixed up, grouped into fives on a table and the square root taken from them, in this case 24 samples. Ten different times was the square root of the number of samples selected, care being

taken to have an even distribution of samples. The results are tabulated below:—

No.	M.	G.	S.	W.	D.
1	15·4	8·4	9·0	4·1	6·5
2	14·7	5·8	10·9	4·3	8·5
3	17·0	6·5	6·9	3·1	6·7
4	14·2	7·9	9·5	2·5	7·9
5	14·1	7·3	8·3	4·4	8·2
6	11·5	5·3	9·1	3·3	10·3
7	15·0	5·7	7·1	3·5	7·8
8	18·3	8·2	8·1	2·8	7·7
9	15·9	6·9	8·8	2·5	6·6
10	17·0	6·2	8·6	3·2	7·9

No.	S.	O.D.	Good.
1	9·0	34·2	56·8
2	10·9	33·5	55·6
3	6·9	33·5	59·6
4	9·5	33·4	57·1
5	8·3	33·5	58·2
6	9·1	30·3	60·6
7	7·1	32·1	60·8
8	8·1	35·3	56·4
9	8·75	32·0	59·25
10	8·6	34·4	57·0

The errors are seen to be 1·3 per cent., 2·5 per cent., 1·5 per cent., 1 per cent., 0·1 per cent., 2·5 per cent., 2·7 per cent., 1·7 per cent., 1·15 per cent., 1·1 per cent. These are negligible.

CONCLUSIONS DRAWN FROM EXPERIMENT ON SQUARE ROOT METHODS.

1. Out of 30 tests made on accuracy, 25 gave an error of less than 3 per cent.

2. Those cases in which the error was greater were due to bad selection of the samples.

3. It seems to be certain that if the sampling is made to go over the whole consignment as equally as possible, that the error accruing therefrom is not big enough to cause a significant inaccuracy.

4. In the cases of consignments of unequal quality care must be taken to have samples selected with equal intervals between bags. They must be so distributed as to cover the whole consignment.

5. When the cacao is even the necessity is not so great. An error must always be expected. The results are accurate enough for our purposes.

PAPER No. VII.

PRINCIPLES UNDERLYING THE DETERMINATION OF ERROR IN CACAO-SAMPLING.

BY W. H. BECKETT.

In any investigation involving the use of figures to represent characteristics there are different classes of errors. It is usual to refer to the characteristic as an " attribute " of an " individual " in a " population." In this particular case, slatiness is an attribute of the individual, a cacao bean, in the population, which is a consignment consisting of a number of bags of cacao.

The procedure is, briefly, as follows. In a consignment of a number of bags we wish to know the percentage of beans which have certain defects—mould, slatiness, weevil attack, etc. To arrive at these figures, samples are drawn from a proportion of the bags only: the proportion is the square root of the total number of bags. If the consignment is of 1,600 bags, the number of samples is $\sqrt{1,600}$, or 40. These 40 samples are obtained by inserting a cone-shaped sampling tool through the canvas mesh of the bag and allowing the beans to fall through a longitudinal slot into the body of the sampler. These samples are then taken, one at a time, exactly 100 beans counted out, and each bean examined. Counts of each defect are made and entered up. When all the samples have been examined we have a mass of figures, each column representing a particular defect and each row a particular sample. The columns are totalled and the totals divided by the number of rows (samples). The figures thus obtained give the percentages. The problem is to find out how far these percentages represent the actual percentages for the whole number of beans, *i.e.*, the percentages which would be obtained if every bean in the consignment was examined. It is for this reason that an investigation of the errors involved is necessary.

PERSONAL ERROR.

The first class of error may be termed " personal." If two observers made a count of the slaty beans, they might obtain different figures, as the attribute " slatiness " is not a definite " presence and absence " factor. One bean may be on the borderline and be classed as slaty by the first observer but passed by the second. The same error arises in the case of all attributes which are of a qualitative nature. For this reason they are sometimes termed " variables," to differentiate them from the purely quantative attributes, such as " silver " or " alloy " in a count of coins. This type of error cannot be eliminated, but by standardisation it

is reduced to a negligible quantity. If all observers tend to over-estimate, or to under-estimate, a variable, the local result is not rendered unreliable, though in comparing, say, the percentage of mouldy beans given by the inspection on the Coast with that given by an observer in Liverpool it would be necessary to know the relative standards used, and an allowance made if the standards were found to differ. The other personal error is that of pure count. In handling hundreds of samples, an observer is liable to make a wrong count, but the occurrence is rare, and insignificant, especially as the effect of one wrong count is divided by the number of samples in taking out the mean percentage.

MECHANICAL ERROR.

The second type of error is mechanical. In taking samples the method used may introduce "bias." An example of this bias is the selective property of the sampling tool used. If the slot were a quarter of an inch wide only, there would be a definite bias, as only beans under that size would pass through. The slot in the sampling tool used is therefore of a fixed size, and all tools must be exactly the same. In the act of moving the tool while inserted in the bag, the heavier beans might find their way into the slot more easily than the lighter ones. These errors were investigated by weighing, measuring length, breadth and width, and making counts of defects, of beans in a series of samples taken both with the tool and by hand, from the bag and from the bulk. Analysis of the figures shewed that such errors are very small, and may be neglected in practice, though they are of considerable technical interest. Thus, for practical purposes, the sampling tool used has no selective bias.

ERRORS OF METHOD OF SAMPLING.

The third and most important type of error is that due to method, and to appreciate it, we must treat it from a statistical standpoint. As it is impossible to examine every bean, and we resort to partial sampling, the number and size of the samples are important. First, let us take the number. If from ten bags we take one sample, we are taking 1 : 10 chance. If, however, in 100 bags we take 10 samples (the same arithmetical proportion, 10 per cent.), the chance is not 1 : 10. For example, suppose that 10 per cent. of the bags were of poor quality, we should arrive at the correct percentage by taking one sample from a bag of poor quality and nine of good quality. In our first sample we have a 10 : 100 (or 1 : 10) chance of drawing a poor one. After that the chances would be 10 : 99, 10 : 98, etc., until a poor one was drawn, when the numerator of the chance ratio would change. The sum of these chances is clearly not 1 : 10. The chance in any method can be calculated, and provided the method conforms to certain rules of "random" sampling, the chance remains the same, irrespective of the size of the population, if the number of samples is not less than 10, and is a function of $\sqrt{2N}$ where N is the total number of units (bags). By random sampling is meant, samples

taken at random throughout the population. In theory, when a sample is taken (say, of coloured balls from a bag), the ball should be returned before the next is taken. This is practically the case when, in taking cacao samples, they are taken over the whole heap of bags, or as the bags are being handled on the beach. The samples are distributed as evenly as possible over the whole consignment. This is as near as can be got in practice to the theoretical "random" sampling.

For these reasons no method of taking a definite percentage sample, irrespective of the total number of bags, can give as reliable a result. Every tenth bag in 1,000 bags would give a very reliable result, but every tenth bag in 30 bags a result of no value. This $\sqrt{2N}$ method aims at keeping the "precision" (*i.e.*, the reciprocal of the "chance"), a constant, and the square root method in use approximates very closely to the ideal.

STANDARD DEVIATION AND PROBABLE ERROR.

Here again we are dealing with variables and not true attributes, as the percentage of defective beans varies from bag to bag. We are not dealing with a number of units of which some have the attribute "slaty" and others not. Each bag may have from 0 per cent. to 100 per cent. of slaty beans. This gives rise to another set of errors, always associated with the partial sampling of variables. The arithmetic mean of the figures of all the samples gives us an average, but no information of its reliability. If we took the differences of all samples from this mean and summed them without reference to their sign (± or —), a figure termed the average deviation is obtained by dividing the total by the number of differences (samples). This gives us some idea of the variability of the samples. From mathematical considerations a quantity known as the "standard deviation" is much more useful, as from it the reliability of the mean can be calculated. The standard deviation is the square root of the mean of the squares of the differences between the separate counts and the mean. If n is the number of samples, and d_1, d_2, d_3, etc., the differences between the counts 1, 2, 3, etc., and the mean of all counts, then the standard deviation is given by $\sqrt{\dfrac{d_1^2+d_2^2+d_3^2+d_4^2+\cdot\ \cdot}{n}}$

From this the probable error, E, is obtained by taking 0·67 x standard deviation. This quantity is important. It is an EVEN chance that the true count lies between ± E of the observed count. This is the probable error of only one observation. The "E" of the mean is obtained by dividing this figure by $\sqrt{n}$, where "n" is the number of observations. From this we can calculate the "precision," or reliability, of a result, and see to what extent the heterogeneous nature of the population affects the percentages. In practice it is usually expressed as a percentage of the mean, and is known as the "Coefficient of Error." It is then in a form suitable for comparison. The coefficients of error have been calculated for different method of sampling—$\sqrt{N}$, $\sqrt{2N}$, $2\sqrt{N}$, etc.,

and an analysis of these figures shows that $\sqrt{N}$ gives a suitable number of samples, taking into consideration "precision" and practicability.

The size of the sample, 100 beans out of about 70,000 in a bag, is chosen primarily because it gives direct percentages. The case of error is similar to that above. Here the question is how far the sample represents the cacao in the bag, whereas above it was of how far the number of samples represents the whole consignment. The probable error of one sample is found by taking a number of samples from one bag, and analysing the figures. It is clearly no use aiming at a greater precision in the mean of all the samples from different bags, than in the one sample from a bag. The sample must give us as reliable a picture of the cacao in the bag, as the mean of the samples does of all the cacao in all the bags. The analysis showed that the cacao in a bag is as heterogeneous as are the bags in a consignment, and that the precision of a single sample is low. The sampling tool is designed to take as representative a sample as possible. The elongated cone-shaped allows the sample to come from the centre and the outside of the bag in proportion. A layer of six inches all round the outside of the bag contains much more cacao than the next layer of six inches inside it (depending on the cube of the distance from the centre of the bag). The sampling tool gives a more reliable sample than taking a handful of beans from an opened bag.

BULK SELECTION TO BE TESTED.

Between considerations of number and size, come methods of "bulk selection." A large number of samples are taken, and by bulking in lots, the number is reduced. This is permissible in some cases of sampling, provided the final number of samples is not less than ten. Several of these methods were tried and the probable errors calculated, but insufficient data was collected when the writer was transferred to other duties. It is not certain whether bulk selection is possible with cacao samples, and further work is necessary to elucidate the point.

The errors considered above arise mainly because the material is heterogeneous. In a perfectly homogeneous population, the errors are of a definite order and can be obtained by pure mathematics. If the variable is of the order x per cent. in an homogeneous population, the standard deviation is given by

$$\sqrt{\frac{x\,(100-x)}{100}}$$

By a comparison of the theoretical coefficients of error with the errors found by actual experiment in a set of samples, the degree of heterogeneity can be found. Both in a single bag and in a consignment of bags it is high, but by the use of the sampler, and by taking the mean of a comparatively large number of samples, the percentages obtained give a reasonably accurate picture of the cacao in the consignment.

PAPER No. VIII.

EFFECT OF SEA WATER ON MOULD IN CACAO BEANS.

By J. L. SCOTT and W. R. HUDSON.

There has been in the past a certain amount of controversy as to the effect of salt water on cacao beans. In the absence of accurate information, ideas on the subject have been necessarily varied. In the course of their duties, the writers have met many who positively assert that, far from being a disease forming agent, it is actually a prophylactic. The question being one of vital interest, it was thought worth while to conduct a series of investigations.

The Experiments and Their Aims.

While the specific purpose of these experiments was an investigation of the above problem, it was thought fit to attempt to solve some subsidiary problems on the same subject, which, while they were not of such paramount importance, were just as interesting. The work was carried out along the following lines:—

(*a*) Effect of salt water on mould formation in cacao beans and on weevil development in cacao beans.

(*b*) Comparative effects of salt and fresh water on mould in cacao beans.

(*c*) Effect of delay in drying wet cacao beans.

In order to obtain reliable information, a series of experiments was carried out. Owing to the fact that the cacao available was limited, work was necessarily slow. The weights of bags employed during the investigation were much less than those of commercial bags, and the results obtained can only be taken as general indications. A detailed description of Experiment I will explain the general procedure adopted throughout.

EXPERIMENT I.

A quantity of cacao weighing 130 lbs. was bulked on the ground, thoroughly mixed, and analysed by taking the average of 20 samples removed therefrom,

ANALYSIS TAKEN BEFORE WETTING.

No.	Mouldy.	Weevilly.
1	3	5
2	2	7
3	3	6
4	2	5
5	7	1
6	3	1
7	5	4
8	2	4
9	5	4
10	2	5
11	3	8
12	4	3
13	4	2
14	3	2
15	4	2
16	2	2
17	5	5
18	6	5
19	2	4
20	4	4
Total	71	76
Average	3·7	3·8

Taking the averages of the first, second, third and fourth series of five samples, it will be seen that they all fall between 3 and 4 per cent. This result may therefore be considered accurate, and in addition, the cacao would seem to have been well mixed. It will be noticed that slight variations occur, but this is naturally inherent in any methods of sampling.

The cacao was divided into three parts of equal weight, each of which was placed in bags, which were treated thus:—

Bag No. 1.—Saturated in sea water and left undried.

Bag No. 2.—Saturated in sea water and dried immediately.

Bag No. 3.—Control bag.

The bags were stored under exactly similar conditions and analysed at weekly intervals throughout one month, this being approximately the time elapsing between shipment and delivery at the port of destination. As each bag weighed only 43 lbs., an accurate reading could be obtained by using the average of five samples. In the other experiments, which were carried out, different treatment was accorded the bags in order to suit the ends in view, but the general procedure was the same. The results obtained will now be considered under the headings already given.

Effect of Salt Water on Mould in Cacao.

The following tables give the result of three series of investigations:—

Date of Analysis.	Bag wet in Sea Water and left undried.		Control Bag.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
	EXPERIMENT I.			
7/12/27 before Wet	3·7	3·8	3·7	3·8
14/12/27 after ,, ...	50·8	6·0	2·6	5·8
21/12/27 ,, ,, ...	55·8	6·6	4·8	4·2
28/12/27 ,, ,, ...	60·8	6·2	3·0	5·6
4/ 1/28 ,, ,, ...	61·2	6·2	5·0	4·2
	EXPERIMENT II.			
17/12/27 before Wet	1·9	0·3	1·9	0·3
24/12/27 after ,, ...	41·6	0·0	2·4	0·4
31/12/27 ,, ,, ...	62·8	0·0	2·8	0·6
7/12/27 ,, ,, ...	70·4	0·4	2·6	0·2
14/12/27 ,, ,, ...	72·2	0·0	3·4	0·0
	EXPERIMENT III.			
23/12/27 before Wet	2·4	0·3	2·4	0·3
30/12/27 after ,, ...	49·8	0·0	2·4	0·2
6/ 1/28 ,, ,, ...	75·2	0·4	3·6	0·2
13/ 1/28 ,, ,, ...	79·6	0·0	3·8	0·0
20/ 1/28 ,, ,, ...	76·2	1·2	3·0	0·4

These figures leave no doubt as to the effect of salt water on cacao beans. It would seem that the maximum amount of damage is done during the first week after wetting and that then the rise is afterwards more gradual. The conditions under which the cacao was stored were not as favourable to mould formation as are those on cargo vessels. The bags were small, allowing of more rapid drying, and the open verandah afforded free access to any wind which might have come. One would therefore expect a larger rise in percèntage of mould in cacao stored in the hold of a ship. There is no evidence to show that weevil also is in any way affected.

Comparative Effects of Sea Water and Fresh Water on Cacao-Beans.

It is very difficult to make an accurate comparison between the mould forming capacities of these two agents. The actual judgment of mouldy beans is done by the naked eye and is not by any means absolute. No two bags of cacao can be subjected to exactly the same influence, nor can the beans be said to be wet to exactly the same degree. Our purpose, however, is to give a general indication and to find out whether the difference between the two is large enough to be of economic significance.

Knowing the difficulties which have just been mentioned, great care was taken to ensure as similar conditions as possible for the two bags treated. Both weighed exactly the same, and were immersed in their respective fluids for two minutes. They were stored side by side and then subjected, as nearly as possible, to

the same external influences. Only one experiment was carried out, and the results are given below:—

Date of Analysis.	Cacao Wet in Sea Water.		Cacao Wet in Fresh Water.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
23/12/27 before Wetting ..	4·7	0·3	4·7	0·3
30/12/27 after ,, ..	49·8	0·2	57·2	0 0
6/ 1/28 ,, ,, ..	75·2	0·4	73·2	0·2
13/ 1/28 ,, ,, ..	79·6	0·0	80·8	0·0
20/ 1/28 ,, ,, ..	76·2	1·2	80·6	0·2

This evidence would seem to indicate that there is no significant difference between salt and fresh water as mould formers in cacao beans. Similar absorption probably gives identical mould formation.

Effect of Drying Cacao Wet by Sea Water.

It has already been mentioned that cacao which has been thoroughly saturated by sea water is sent back to store and dried. Some period usually elapses between wetting and drying, however, and it was thought worth while to investigate the effect of such delays.

The following tables show the results of drying immediately and delaying for 24, 48 and 72 hours respectively. By drying is meant exposure to sun until the crispness of good commercial cacao is obtained.

Drying Immediately.

Date of Analysis.	Dried immediately after Wetting.		Control.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
	EXPERIMENT I.			
7/12/27 before Wetting ..	3·7	3·8	3·7	3·8
14/12/27 after ,, ..	3·4	3·6	2·6	5·8
21/12/27 ,, ,, ..	4·2	1·8	4·8	4·2
28/12/27 ,, ,, ..	4·4	4·8	3·0	5·6
5/ 1/28 ,, ,, ..	6·0	3·6	5·0	4·6
	EXPERIMENT II.			
17/12/27 before Wetting ..	1·9	0·3	1·9	0·3
24/12/27 after ,, ..	2·4	0·4	2·4	0·4
31/12/27 ,, ,, ..	3·4	0·2	2·8	0·6
7/ 1/28 ,, ,, ..	3·4	0·2	2·6	0·2
14/ 1/28 ,, ,, ..	4·0	0·4	3·4	0·0

Drying immediately after wetting prevents the formation of mould.

Drying 24 Hours after Wetting.

In Experiment 3, one bag of cacao wet in sea water was allowed to remain for 24 hours before it was thoroughly dried in the sun.

Date of Analysis.	Dried 24 hours after Wetting.		Control.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
23/12/27	2·4	0·3	2·4	0·3
30/12/27	4·2	0·4	2·4	0·2
6/ 1/28	3·6	0·2	3·6	0·2
13/ 1/28	7·2	0·2	3·6	0·0
20/ 1/28	7·0	1·0	3·0	0·4

A significant increase will be observed.

Drying 48 Hours after Wetting.

Another bag in Experiment 3 was allowed to remain wet for 48 hours before drying.

Date of Analysis.	Dried 48 hours after Wetting.		Control.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
31/12/27	3·6	0·1	3·6	0·1
7/ 1/28	10·6	0·2	3·4	0·0
14/ 1/28	11·4	0·4	4·0	0·2
21/ 1/28	13·0	0·2	4·0	1·0
28/ 1/28	13·0	1·2	4·5	0·8

The increase is quite easily seen to be a large one.

Drying 72 Hours after Wetting.

Date of Analysis.	Dried 72 hours after Wetting.		Control.	
	Mouldy.	Weevilly.	Mouldy.	Weevilly.
31/12/27	3·6	0·1	3·6	0·1
7/ 1/28	19·0	0·2	3·4	0·0
14/ 1/28	19·2	0·4	4·0	0·2
21/ 1/28	18·6	0·2	4·0	1·0
28/ 1/28	18·4	0·4	4·5	0·8

The figures show that the delay between wetting and drying is a very important factor in the formation of mould, the percentage increase being indirectly proportional to the length of time delayed.

It would seem that every day lost in removing moisture from beans has a deteriorating effect on the cacao. Immediate and thorough drying is the only method of combating mould formation.

CONCLUSION.

It is now apparent that absorption of sea water by cacao is just as conducive to mould formation as that of fresh water, though it is possible that there is a difference in the types of mould formed. Further investigation to differentiate these types would be of academic interest, but does not fall within the scope of this paper.

PLATE III

PLAN OF CACAO FIELD. ASUANSI

NORTH

WEST | | | | | | | EAST

207		156	102		50	49	
206	157	155	103	101	51	48	1
205	158	154	104	100	52	47	2
204		153	105	99	53	46	
203	159	152	106	98	54	45	3
	160	151		97	55	44	4
202	161				56	43	
201		150	107	96	57	42	5
200	162	149	108	95	58	41	6
199		148	109		59	40	
198	163	147	110	94	60	39	7
197	164	146	111	93	61	38	8
196		145	112		62	37	
195	165	144	113	92	63	36	9
194	166	143	114	91	64	35	10
193		142	115	90	65	34	
192	167	141	116	89	66	33	11
191	168	140	117	88	67	32	12
190	169	139	118	87	68	31	
189	170	138	119	86	69	30	13
188	171	137	120	85	70	29	14
187	172	136	121	84	71	28	
186	173	135	122	83	72	27	15
185	174	134	123	82	73	26	16
184	175	133	124		74	25	
183	176	132	125	81	75	24	17
182	177	131	126	80	76	23	18
181	178	130	127		77	22	19
180	179	129	128	79	78	21	20

SOUTH

— COLA SHADE TREES

— BLANK PLANTING SPACES

PAPER No. IX.

VARIATIONS IN THE YIELDS OF CACAO TREES AT ASUANSI EXPERIMENT STATION.

(The field-trials discussed in this paper have been conducted successively by A. B. CULHAM *and* J. STEELE. *The paper has been prepared by* G. G. AUCHINLECK.—*Editor.)*

Details of the Trials.

The field dealt with in this paper was planted in 1910. The variety of cacao used was Forastero Amelonado, the type which is general all over the Gold Coast (see Bulletin 4 of the Department of Agriculture). An unusually wide planting-distance was adopted, the trees being set out in squares 15 feet apart. There were, in all, eight planting-lines of 29 trees each, or 232 squares of 225 square feet each (15 ft. by 15 ft.), so that the total area was 52,000 square feet, or 1·1983 acres. 207 of the planting-squares were occupied by cacao, 20 by cola-trees used as shade, and five were left blank.

Plate III shows the general arrangement of the field. The figures are the serial numbers of the cacao-trees, the large crosses indicate cola shade-trees, and the small crosses mark unoccupied squares.

The shape of the field, with a length about $3\frac{1}{2}$ times as great as the breadth, results in a high proportion of boundary to area. The actual ratio is 1,110 feet to 52,200 square feet, against a boundary-length of 920 feet to a square of the same area. Plants in the outer or boundary squares are clearly under different conditions to those inside, a difference which may or may not be beneficial, and which may cause some irregularity in yields.

In 1919, when the trees were nine years of age, individual yields of each tree were recorded, and this has been continued regularly since. The tabulated records up to the end of 1926 numbered 1,563, and are too lengthy to reproduce in this paper.

The use of these yield-records as a guide to the selection of high-yielding individuals and at the same time as a means of testing the uniformity of the field appears to involve a contradiction. The first application is based on the assumption that the bearing-powers of the individual trees differ inherently from one another, while the second assumes that differences in the yields of the trees are caused by soil irregularities. The truth probably lies somewhere between the two opposite assumptions. There are inherent differences between individual trees, but the effect of these differences is probably neutralised by the fact that planting was done at random, there having been no conscious arrangement of the different types.

The Field Considered as a Whole.

By summing the yields of all trees, we get the annual yields of the field, which are given in Table I below. The figures for number of pods, the unit in which yields are recorded at the Experiment Station, are converted into pounds of cured cacao

by dividing by 12·5. Ratios of eight and ten pods per pound of cured cacao, found by H. A. Dade (see Bulletin 6 of the Department, pp. 18 and 19), in the cases of farms in the Anyinam area, are too high to be applicable to Asuansi figures. Ratios determined at Asuansi over the whole crops of two fields of Forastero Amelonado for the years 1918 to 1925 (totals of 90,191 and 62,447 pods respectively, being concerned), were 12·0 and 12·8 (see Bulletin 4 of the Department, pp. 23 and 28).

The mean yield of cured cacao per acre in Table I below (674 lbs.), indicates that the field under consideration is slightly above the average in productive power. Fields of Forastero Amelonado on seven local Experiment Stations gave yields which, over an aggregate of 93 years, averaged 595 pounds (Bulletin 4 of Department, page 7). Valid comparison is not possible in every case, since the planting-distances vary considerably, thus:—

Present Field	planted at	15′	×	15′	(203 plants per acre)
Aburi Field	,,	15′	×	15′	(203 ,, ,, ,,)
Asuansi Field V.	,,	10′	×	10′	(435 ,, ,, ,,)
Kibi, Kumasi and Wiawso	,,	12′	×	12′	(302 ,, ,, ,,)
Peki	,,	8′	×	15′	(363 ,, ,, ,,)
Kpeve	,,	12½′	×	12½′	(278 ,, ,, ,,)

The optimum planting-distances for different soils and climates of the Gold Coast have not been determined. From the fact that the cacao-flower is not light-loving, it seems probable that close planting, up to a greater degree than is usual, may be profitable, particularly if no shade-plants are provided for the field.

Annual Fluctuations of Yield.

The yields of the field are given in the following Table I:—

TABLE I.

YIELDS OF THE WHOLE FIELD.

Year.	Total pods reaped.	Yields per acre.	
		Pods.	Pounds of cured Cacao.
1919	9,568	7,985	639
1920	11,585	9,668	773
1921	10,948	9,136	731
1922	9,450	7,886	634
1923	10,916	9,110	729
1924	9,733	8,122	650
1925	7,278	6,073	486
1926	11,338	9,462	757
Means	10,102	8,430	674

The period of observation is hardly long enough to determine whether the yields are governed by any regular fluctuations, unless the alternation of one low yield with two high ones, observable in the Table, be significant. The yields of perennials are supposed to rise and fall in definite rhythm, which is presumably the resultant of phenomena of exhaustion interacting with meteorological cycles.

There are no signs of lessening yield apparent in these figures, though we shall see later that the constant yields really represent a state of equilibrium between a falling yield of one-half and a steadily rising yield of the other half of the field. The trees are sixteen years old and have had no manuring.

Following is a summary of the results in Table I, shewing the range of annual fluctuations in yield which may be used as an indication of the limits of probable future yields:—

Mean yield of the periods concerned.		Average deviation from means.	Range of yield probable.	Actual yield in following year.
(Pods per acre.)				
1st year	7,985	—	—	9,668
„ 2 years	8,826	± 9·53	7,985–9,668	9,136
„ 3 „	8,930	± 7·05	8,300–9,560	7,886
„ 4 „	8,669	± 8·46	7,936–9,402	9,110
„ 5 „	8,757	± 7·50	8,100–9,414	8,122
„ 6 „	8,651	± 7·57	7,998–9,304	6,073
„ 7 „	8,283	± 10·57	7,407–9,159	9,462
„ 8 „	8,430	± 10·84	7,516–9,344	—

The ranges of variation are great, and in spite of this three yields (7,886, 6,073, and 9,462) fall outside of the indicated ranges. Without any special treatment, it is probable that the 1927 yields will be somewhere between 7,516 and 9,344 pods per acre. Any increase of yield, following on beneficial treatment, would have to be above the top figure of this range before it could be considered significant. The figures illustrate the difficulty experienced in obtaining accurate and reliable results from this method of experiment, as very few methods of treatment are beneficial enough to produce an increase of yield of more than 10·84 per cent. in one year. The treatment would have to be continued for several years until a new mean, for the yields after treatment, had been obtained.

Degree of Uniformity of the Field.

To obtain evidence as to the degree of uniformity of the field, we may consider the field as made up of a selected number of areas and compare the yields of the trees on each area. In Table II below, figures are given for the yields of quarters of the field, quartering being effected in three different ways.

The resultant plots are as follows:—

E, EM, WM, and W obtained by quartering the field into four longitudinal strips by three lines running from North to South.

N, NM, SM, and S obtained by quartering the field by three lines running from East to West.

NE, NW, SE, and SW obtained by quartering the field into corner-plots by two median lines, running from North to South and from East to West respectively.

In each case, the yields per plot have been re-calculated to fifty trees so as to allow for losses or surpluses of trees.

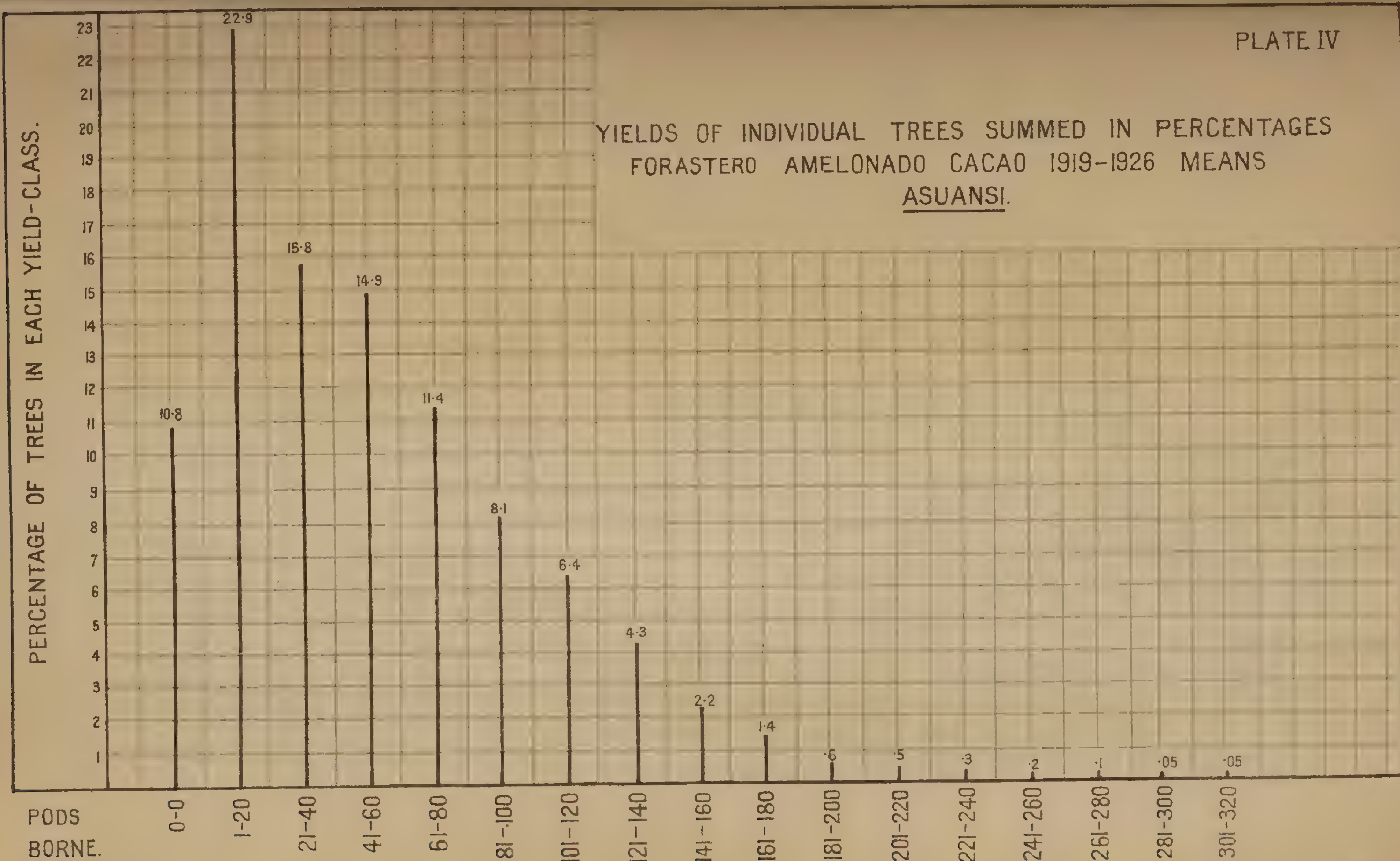
TABLE II.
FIELD CONSIDERED AS FOUR PLOTS.

Plot Nos.	Yields in Number of Pods per 50 Trees.								Mean of 8 Years.	Average Deviation % Mean.
	1919	1920	1921	1922	1923	1924	1925	1926		
	A. (Field Quartered by N to S Lines)									
E ...	2,049	3,185	2,957	2,913	3,637	4,351	3,043	4,662	3,350	± 19·4
EM ...	2,398	3,048	2,317	2,737	2,751	2,873	2,242	3,827	2,774	± 12·8
WM ...	2,226	2,552	2,568	1,988	2,233	1,625	1,156	2,013	2,045	± 17·1
W ...	2,569	2,549	2,427	2,173	2,831	1,496	1,278	1,484	2,102	± 24·3
Mean ...	2,310	2,833	2,567	2,453	2,863	2,586	1,930	2,996	—	—
Average Deviation % Mean ...	± 7·5	± 10·0	± 7·6	± 15·2	± 13·4	± 39·7	± 36·9	± 41·6	—	—
	B. (Field Quartered by E to W Lines)									
N ...	2,409	2,993	2,250	2,122	2,326	1,994	1,487	2,450	2,254	± 12·9
NM ...	1,902	2,658	3,276	2,604	3,075	3,457	2,502	3,407	2,860	± 15·5
SM ...	2,631	3,231	3,247	2,551	3,503	2,988	2,083	3 195	2,929	± 12·9
S ...	2,362	2,509	2,369	2,439	2,347	1,684	1,443	2,569	2,215	± 14·7
Mean ...	2,326	2,848	2,785	2,429	2,813	2,531	1,879	2,905	—	—
Average Deviation % Mean ...	± 9·1	± 9·3	± 17·1	± 6·3	± 16·9	± 27·3	± 22·0	± 13·6	—	—
	C. (Field Quartered into Corner-Plots)									
NE ...	2,318	3,411	3,582	3,183	3,376	4,131	2,906	3,433	3,292	± 11·2
NW ...	1,918	2,235	2,096	1,669	2,162	1,534	1,230	1,585	1,804	± 16·6
SE ...	2,170	2,862	2,778	2,578	3,000	3,087	2,374	3,901	2,844	± 12·9
SW ...	2,723	2,806	2,875	2,447	2,847	1,587	1,205	1,911	2,300	± 23·9
Mean ...	2,282	2,828	2,833	2,469	2,846	2,585	1,929	2,707	—	—
Average Deviation % Mean ...	± 10·4	± 10·9	± 13·9	± 16·6	± 12·0	± 39·6	± 36·8	± 35·4	—	—

During 1919 and 1920 the field was fairly uniform, the average deviations in yields of plots being small (± 7·5 and ± 10·0 per cent. for Case A, ± 9·1 and ± 9·3 for Case B, and ± 10·4 and ± 10·9 for Case C). In later years, the deviations increased considerably, reaching maxima of ± 41·6, ± 27·3 and ± 39·6 in the three cases. The reasons for these increases, deducible from the figures and confirmed by knowledge of the field, are the gradual improvement in yield of the Eastern half of the field and the progressive exhaustion of the poorer soil of the Western half. In Case A, the contrast of the E and EM plots with the W and WM areas is very marked, as is aso the gradual decline in yield of the last two. A further indication of this is given by the high annual deviations (± 16·6 and ± 23·9) of plots NW and SW in Case C.

This lack of uniformity precludes the use of the field for ordinary comparative experiments. A line of work which should be carried out is the improvement of the Western half by special treatment. The field should be divided into eight plots by one North-to-South line and three lines East-to-West, and the resulting four Eastern plots retained as controls without special treatment. The four Western plots should be forked, and each treated with a different system of manuring. Mulch, a complete artificial

PLATE IV



Reproduced at Survey H.Q. Accra, 1928.

mixture, pen manure or compost, and slag and potash suggest themselves. The trial would be of special interest in view of the lack of knowledge, locally, of the effects of manures on cacao.

Individual Yields of the Trees.

As the individual records of each tree are too numerous to publish here, they are summarised in the frequency-lists given in Table III, and in the graph opposite (Plate IV).

TABLE III.

(FREQUENCY CURVES OF INDIVIDUAL YIELDS.)

Number of pods borne.	Number of Trees in Each Class.								Mean percentage of Trees in Each Class (8 years).
	1919	1920	1921	1922	1923	1924	1925	1926	
0	23	17	13	11	27	35	26	26	10·8
1–20	37	34	40	54	37	60	55	45	22·9
21–40	34	33	29	38	36	19	29	28	15·9
41–60	45	39	25	25	32	24	25	19	14·8
61–80	37	25	23	19	28	11	17	18	11·4
81–100	15	20	22	19	13	12	10	15	8·1
101–120	10	18	15	16	16	9	7	9	6·4
121–140	4	13	14	3	8	11	3	11	4·3
141–160	1	3	6	4	6	7	4	4	2·2
161–180	1	2	3	2	2	5	4	3	1·4
181–200	—	1	—	2	1	2	1	2	·6
201–220	—	—	—	—	1	2	—	4	·5
221–240	—	—	—	—	1	1	—	2	·3
241–260	—	—	—	—	—	—	—	3	·2
261–280	—	—	—	—	—	—	1	1	·1
281–300	—	—	—	—	—	1	—	—	·05
301–320	—	—	—	—	—	—	—	1	·05
Total Number of Trees	207	205	194	192	192	191	191	191	100·0

A noteworthy feature of this table is the increase of range as the trees grow older. In 1919 the extreme range was 0—180 pods, while in 1926 it had become 0—320. The gradual improvement of the Eastern and the deterioration of the Western half of the field are the chief cause of the increased scattering.

The distribution curve shown in the graph is an unusual one in that the mode (or highest point) is not central between the two extremities of the curve, but occurs near one extremity. Cola trees apparently give a similar type of curve, as exemplified by the curve given in the 1926 Year Book of the Department (Bulletin 7), in the graph facing page 56.

Selection of the Best Yielding Trees.

In order to make use of the mass of records which have been collected, it is necessary to devise some method of analysing the figures so that the consistently productive trees may be isolated.

The Western half of the field is gradually declining in productivity, and in consequence the individual yields are lower here than in the Eastern half. For this reason a mere selection of the

highest yielders in the whole field would not be satisfactory, since many of the plants on the poorer half, though lower in yield, may be inherently superior to those of higher yield on the better half.

In order to overcome this difficulty, the device has been adopted of taking the highest yielders in each half separately for each year, and then testing their continued productivity by noting the number of times that each tree falls into the highest yield-classes. An arbitrary number of the ten highest yielders in the Eastern half and of fifteen in the Western half has been taken for consideration each year. The selections therefore amount to about one-eighth or twelve per cent. of the total number of trees in the field.

The result of this method of selection has been that forty-one trees have emerged which, during the eight years, held all the honours in the Eastern half (80 possible places), while 61 divided the honours for the available 120 places in the Western half. Those trees, which secured a place more than twice, are given in the following Table IV. For purposes of comparison, the mean of all trees in each half of the field is inserted in the Table.

TABLE IV.

(Plants selected for consistently good yields.)

Serial Numbers of Trees.	Times Occurring among Highest Yielders.	Number of Pods Borne by Trees. 1919	1920	1921	1922	1923	1924	1925	1926	Total Number of Pods in 8 Years.
		(EASTERN HALF OF FIELD.)								
Mean Yield of Trees in Eastern Half ..	—	45	63	63	60	68	85	62	96	542
5	Five	72	56	103	161	128	282	152	212	1,166
43	Six	32	137	158	160	133	175	42	223	1,060
41	Three	72	126	105	112	80	220	158	141	1,014
37	Four	65	49	169	117	145	164	126	160	995
58	Three	76	115	100	51	24	154	166	267	953
35	Four	43	174	59	39	71	192	165	193	936
38	Three	39	107	149	28	94	137	136	243	933
40	Three	5	59	128	95	99	211	150	115	862
70	Three	36	60	97	84	136	136	167	135	851
88	Three	78	97	147	44	156	137	25	74	758
54	Three	64	122	106	134	126	75	97	34	758
69	Three	89	107	137	17	35	66	81	220	752
84	Three	79	106	81	62	67	19	73	133	620
		(WESTERN HALF OF FIELD.)								
Mean Yield of Trees in Western Half ..	—	47	53	52	42	50	29	24	36	333
176	Four	49	139	54	56	146	136	168	254	1,002
143	Four	68	57	57	112	92	165	81	234	866
115	Five	69	58	159	89	201	96	69	110	851
142	Five	71	78	125	103	148	115	108	68	816
132	Four	165	129	96	176	108	75	8	57	814
144	Five	78	78	139	13	108	126	68	133	743
112	Five	36	107	148	109	57	108	32	134	731
197	Three	57	127	86	62	152	130	56	46	716
98	Four	122	147	162	154	98	3	0	0	686
183	Four	131	34	68	83	113	69	79	94	671
133	Three	32	66	64	99	105	78	53	104	601
148	Four	107	5	151	94	62	85	44	1	549
198	Three	122	0	136	138	37	3	3	0	439
194	Three	93	38	13	35	62	95	61	23	420

With very few exceptions, the trees given in Table IV are among the highest as well as the steadiest yielders in the field. Trees No. 98 and 198 may be accepted with little doubt as victims of the poverty of the soil.

There are in the field other trees equal in yield to those in Table IV, but which attained only once a place among the honours or which yielded steadily and well, but missed a place each year. These are given in the supplementary Table below, and they complete the list of all trees in the field which gave yields higher than 750 and 450 pods in the eastern and western halves respectively.

TABLE V.

SUPPLEMENTARY LIST OF HIGH-YIELDING TREES.

Serial Numbers of Trees.	Times among Highest Yielders.	Number of Pods Borne by Trees.								Total for 8 Years.
		1919	1920	1921	1922	1923	1924	1925	1926	
		(EASTERN HALF OF FIELD.)								
34	Twice	14	118	115	190	182	148	79	164	1,010
76	Twice	54	98	116	92	85	223	86	253	1,007
55	Twice	86	177	98	11	38	148	55	311	924
45	Twice	50	49	88	120	114	195	107	122	845
30	Twice	16	70	112	101	120	179	95	201	824
31	Once	0	123	99	82	119	141	101	120	785
63	Twice	8	18	63	88	84	118	196	203	778
39	Once	3	110	54	68	50	149	150	172	756
77	Twice	157	84	68	120	32	94	63	137	755
		(WESTERN HALF OF FIELD.)								
197	Twice	57	127	86	62	152	130	56	46	716
125	Twice	73	103	133	91	96	56	40	95	687
166	Twice	63	28	70	66	225	170	43	0	665
111	Twice	38	56	121	27	143	55	48	100	588
175	Twice	55	105	94	75	129	27	57	40	582
174	Once	65	82	73	85	117	31	57	42	552
200	Twice	90	85	115	34	179	5	11	29	548
178	Once	112	98	53	66	47	40	36	66	518
186	Twice	52	113	90	103	63	25	29	27	502
173	Twice	124	49	93	17	81	12	18	93	487
145	Twice	36	86	140	101	74	23	6	6	472
195	Twice	48	46	35	15	115	51	72	84	466
192	Once	54	99	43	143	82	1	1	42	465
105	Once	42	33	92	69	70	24	7	119	456

The trees, details of which are given in Table IV and its supplement, will serve as starting-points for the work of selecting and propagating high-yielding strains of cacao. Work of this kind is slow and laborious, particularly when it deals with perennial plants, and steps should be taken to ensure that it is not abandoned just when the stage is reached where results may reasonably be expected.

In the present case, the initial step, but only the initial one, is complete. The history and characteristics of each tree are known for a long enough period to render it certain that minor fluctuations and exceptions have been observed and can be discounted. The next step is the propagation of progeny of the selected plants and their careful trial by the Department. It should not be forgotten that the high yields of these plants may not be inherent but may be due to specially favourable positions in the field, and that trial of the second generation is therefore necessary.

It is clearly useless to grow progeny from seed. It is not known whether cacao is normally self-pollinated or cross-pollinated, nor is the ancestry of the selected trees known. Seed is almost certain to produce plants dissimilar to the parents. A vegetative method is necessary, and as cuttings of cacao grow with exceptional difficulty, recourse must be had to grafts or buds.

PAPER No. X.

VARIATIONS IN THE YIELDS OF CACAO TREES AT ABURI EXPERIMENT STATION, 1914–1926.

(*The trials dealt with in this paper were conducted, and the figures compiled by G. H. Eady. The paper was prepared by G. G. Auchinleck.*—EDITOR.)

In the Annual Report of the Department of Agriculture for 1914, the Director mentioned that the individual yields of cacao-trees of Forastero Amelonado type were being recorded at Aburi. The procedure has been sustained up to the present time, and a voluminous series of records, amounting to over 40,000 individual monthly records of yield, is now available.

It seems clear that the observations were intended to provide information on the variations in yield between individuals in the same year, and also the variations in yield which each individual showed from year to year. In addition, the records would enable the Department to propagate high-yielding types for distribution.

Apart from the use of the records as criteria for selection of high-yielding strains, they have proved of definite value as a means of testing the initial variations in quality of different parts of the field. This aspect is dealt with in another paper in this Year-book (" Initial Variation between Plots used for Manurial Trials," by A. B. Culham and others; Paper No. 11).

The Field Considered as a Whole.

In the beginning of the trial, there were 296 trees in the field, planted at a distance of 15 feet square. The trees were planted in 1891-1893 and were therefore 22 to 24 years old when the trials began, and 35 to 37 years old in 1926. During the period of the trial, 58 of the original trees died and were replaced with young plants. These later replantings are not considered in this paper, attention being confined to the remaining 238 of the original trees.

The total yield of the field, and the mean yield per tree for each year, are given in the following table:—

Year.	Total Yield of Field.	Mean Yield per Tree.
	Pods.	Pods.
1914	33,303	115 (289 trees)
1915	20,660	72 (289 „)
1916	31,738	112 (283 „)
1917	24,867	89 (280 „)
1918	35,264	126 (280 „)
1919	31,614	114 (277 „)
1920	20,535	74 (275 „)
1921	26,699	99 (269 „)
1922	21,603	84 (257 „)
1923	17,567	70 (252 „)
1924	21,812	87 (249 „)
1925	20,284	83 (245 „)
1926	26,167	110 (238 „)
Mean	25,547	95 —

Average deviation per year % mean .. ± 18·9%.

A yield of 95 pods is equivalent to eight pounds of cured cacao, so that an acre of 193 trees (15 ft. by 15ft.) would give an indicated yield of 1,544 pounds of cured cacao. The average yield of Forastero Amelonado for many years at seven local experiment stations has been 595 pounds (Bulletin 4 of this Department). The field is therefore an exceptionally good one.

The yield of the field has lessened during the thirteen years of observation. The mean yield per year for the first six years was 29,574 pods and for the second period of six years was 21,417 pods. The year 1926 was an exceptionally good year. The figures are of interest in view of the doubt which has existed locally in the past concerning the length of productive life of the cacao tree. The trees under consideration in this paper were from 35 to 37 years old in 1926.

Individual Yields of Trees.

The records compiled during the thirteen years of observation are far too voluminous to reproduce in this paper, nor is it necessary to publish them. They can be conveniently summarised in the forms of a distribution-curve. In the following distribution-table are given the number of trees which occur in certain arbitrarily chosen

yield-classes, consideration being limited to the 238 trees which survived throughout the thirteen years of observation:—

Mean number of pods per year per tree.	Number of trees in each yield-class.
11–25	4
26–40	12
41–55	16
56–70	31
71–85	32
86–100	28
101–115	40
116–130	36
131–145	24
146–160	10
161–175	4
176–190	1
—	238

The variations in individual annual yields of the trees were greater than in the case of the means given above, the highest figure recorded being 317 pods and the lowest 0.

Selection of Highest Yielding Trees.

In selecting the best-yielding trees two factors have to be taken into account. In the first place the yields must be high and in the second place the high yields must be sustained. The device has therefore been adopted of tabulating the thirty trees which gave the highest yield in each of the thirteen years under consideration, and then ascertaining whether any trees recurred fairly often among these highest yielders.

Results of this method of classification are given in the following table:—

Total places of honour in 13 years	390
No. of trees which secured no places of honour ...	96
No. securing one honour place	46
,, ,, two honour places	30
,, ,, three ,, ,, ...	23
,, ,, four ,, ,, ...	15
,, ,, five ,, ,, ...	18
,, ,, six ,, ,, ...	5
,, ,, seven ,, ,, ...	3
,, ,, eight ,, ,, ...	1
,, ,, nine ,, ,, ...	1
	238

The mean yields of the trees in these classes during the thirteen years were as follows:—

96 trees securing no honour places, 64 pods per year.

99 trees securing three, two or one honour places, 106 pods per year.

43 trees securing four or more honour places, 142 pods per year.

It seems clear that the method of selection adopted is effective.

The yields each year of the forty-three trees securing four or more honour places during the thirteen years are given in the following table:—

YIELDS OF TREES OCCURRING AMONG FIRST THIRTY MORE THAN THREE TIMES.

Tree No.	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	Total and Years.
20	107	163	156	246	223	320	171	251	144	32	168	75	175	2,331 (8)
156	162	55	193	134	247	422	115	169	211	74	155	125	187	2,249 (6)
203	204	124	243	166	232	245	135	252	103	114	102	166	74	2,160 (9)
49	102	110	84	125	193	260	268	206	57	170	215	43	196	2,129 (6)
167	14	7	141	172	254	448	124	283	107	70	129	207	154	2,110 (5)
48	208	125	33	163	179	218	296	150	229	93	137	41	185	2,057 (7)
130	296	17	266	207	173	346	82	169	52	94	49	183	122	2,056 (5)
129	154	93	194	215	203	267	95	128	216	81	148	88	170	2,012 (7)
43	168	220	89	142	161	317	161	186	34	129	181	34	126	1,990 (7)
220	268	100	241	192	266	169	197	115	73	91	58	92	94	1,956 (5)
97	199	296	150	104	207	213	118	108	133	86	144	26	157	1,943 (4)
6	235	145	200	199	145	297	63	140	84	93	73	125	137	1,936 (5)
22	191	218	72	135	129	284	132	202	107	102	145	35	172	1,924 (6)
179	219	63	151	156	251	226	134	151	156	60	193	121	138	1,919 (6)
277	180	86	175	160	329	205	142	71	136	109	88	69	159	1,909 (5)
176	182	23	144	143	163	161	—	—	122	114	239	204	182	1,877 (5)
70	184	247	71	113	164	67	263	129	76	188	176	72	136	1,876 (5)
187	148	83	136	101	137	110	104	170	174	192	153	191	159	1,858 (4)
161	188	48	227	146	213	266	105	164	138	82	110	37	132	1,856 (5)
275	130	143	95	205	261	116	168	77	141	134	138	76	168	1,852 (5)
162	215	63	209	167	251	69	110	154	73	73	97	68	100	1,849 (5)
16	217	145	130	109	136	269	114	188	142	78	97	55	130	1,820 (4)
196	149	93	187	102	161	121	152	131	187	144	111	130	151	1,819 (4)
99	170	18	135	89	140	220	41	93	191	196	180	149	178	1,810 (5)
88	151	8	100	138	261	113	77	193	161	155	134	112	206	1,809 (5)
100	121	9	180	132	201	160	32	118	210	174	134	148	187	1,806 (4)
188	193	91	156	151	198	82	92	202	190	89	—	226	136	1,806 (5)
136	108	68	122	123	197	214	64	197	162	111	97	175	105	1,783 (4)
218	157	52	130	92	134	144	114	176	177	130	117	170	185	1,778 (5)
119	86	30	127	90	262	150	32	100	167	153	234	131	203	1,765 (5)
139	121	96	173	167	151	96	126	61	124	146	133	130	238	1,762 (4)
121	106	21	147	115	126	160	83	78	112	206	157	166	183	1,760 (4)
182	39	32	203	142	218	256	79	207	130	78	140	88	147	1,759 (4)
215	128	89	142	110	201	71	93	199	180	97	177	145	92	1,742 (4)
264	226	102	188	147	212	151	157	64	232	40	43	42	68	1,677 (6)
164	161	26	189	102	133	161	20	171	138	163	130	106	176	1,676 (4)
243	85	67	121	131	241	95	101	115	175	120	58	221	143	1,673 (4)
133	146	52	197	130	155	234	49	135	75	134	149	89	108	1,653 (4)
198	121	129	123	70	173	82	101	205	169	120	50	175	115	1,633 (4)
116	126	85	154	132	170	69	43	196	158	163	123	161	182	1,562 (5)
263	132	132	149	93	176	107	153	12	159	21	162	173	163	1,562 (5)
120	133	42	163	118	177	134	91	60	117	144	150	87	106	1,522 (4)
173	74	43	155	144	211	103	84	190	154	134	121	81	—	1,494 (5)

The next step necessary in these trials should be the securing of budded or grafted progeny from these forty-three selected trees, and their trial in another field in order to ascertain whether the high yields are due to inherent productiveness of the trees or merely to accidents of locality.

PAPER No. XI.

INITIAL VARIATIONS BETWEEN PLOTS USED FOR CACAO MANURIAL TRIALS.

By A. B. CULHAM.

It has become necessary in recent years that information should be sought regarding the effects of various manurial treatments on typical soils on which cacao is grown in the Gold Coast. As the industry ages the need for maintaining, and increasing if possible, the yields of the older farms becomes increasingly obvious. Expansion to new areas has a limit and a more intensive system than that of present practice is indicated.

The only cacao areas over which the Department has complete control are situated on Agricultural Stations, and it is with these fields that experiment has been begun. The stations selected are Aburi, Kumasi, Asuansi and Kpeve, and each is reasonably representative of the surrounding country. In no case is it superior as cacao land. Broadly, the trial on each station consists of two acres of bearing cacao, divided into eight plots of one quarter of an acre each, but for various reasons not connected with the trials it has been necessary to modify the management in some cases. The age of the trees varies on different stations as does the planting distance. These factors are on each station as below:—

Station.	Date of Planting.	Distance Planted.
Aburi	1891—1893	15′ × 15′
Kumasi	1908—1910	15′ × 15′
Asuansi	1912—1915	10′ × 10′
Kpeve	1913—1914	12½′ × 12½′

The trials are limited to the use of mulching and of the less soluble forms of manures, and these were applied first in August, 1926. By mulching is meant the application, from an outside source, of organic matter, such as leaves, mowings, etc., so as completely to cover the surface of the soil. The dates of application of manure per acre are: Basic slag 8 cwts., Sulphate of Potash 2 cwts., and Dried Blood 4 cwts. The treatment of each plot is as follows:—

Plot	A.	No mulch.	No manure.
,,	B.	,, ,,	Dried blood, sulphate of potash.
,,	C.	,, ,,	Basic slag, sulphate of potash.
,,	D.	,, ,,	Basic slag, sulphate of potash, dried blood.
,,	E.	Mulched.	Manure as Plot A.
,,	F.	,,	,, ,, B.
,,	G.	,,	,, ,, C.
,,	H.	,,	,, ,, D.

Yields from each plot have been recorded separately since 1st August, 1926. The yields dealt with in this paper are for the period from that date to 31st July, 1927. A table is given showing the area of each plot, number of fruiting trees, actual yield and yield per acre. This table shows an extreme variation of yield on the various plots. The Kpeve field shows least variation, but even here the average deviation of the plots from the mean is ±15·7 per cent. The figures for the other stations are Aburi ± 16·9 per cent., Asuansi ± 21·7 per cent., and Kumasi ± 33·4 per cent. Kpeve also heads the list in point of yield with a mean yield per acre of 14,813 pods. The next in order are: Aburi 13,064, Kumasi 9,442, and Asuansi 6,646.

In seeking a solution of the extreme variations in the yields of the plots on individual stations, the following factors, in addition to those of variation in soil and soil conditions suspected as causing them, are worthy of consideration.

(*a*) Relative positions of the plots.

(*b*) Number of fruiting trees per acre.

(*c*) Age of the field.

(*d*) Effect of treatment.

With regard to (*a*), there appears no indication that the relative positions of the plots is of any moment, as may be seen by reference to Plate V and the table of yields. No two fields have been divided in the same way, and there is nothing to show that any one method is superior to another, or that the relative evenness of the Kpeve plots is in any way due to their positions. They are not appreciably more compact than the others, which show a greater variation, and other things being equal, a greater spread argues a greater variety of conditions. Plot C, situated between B and D, produced pods—921 of the mean per acre, whilst the two latter produced pods + 3,055 and + 1,375 of the mean per acre. Asuansi Plot D, which is between C and E, produced pods—2,322 of the mean per acre and C and E + 1,866 and — 1,102 respectively. The Kumasi plots show tremendous variation, ranging from + 4,202 to — 5,170 of the mean yield of pods per acre. Position, as such, therefore, cannot be regarded as a factor controlling variability.

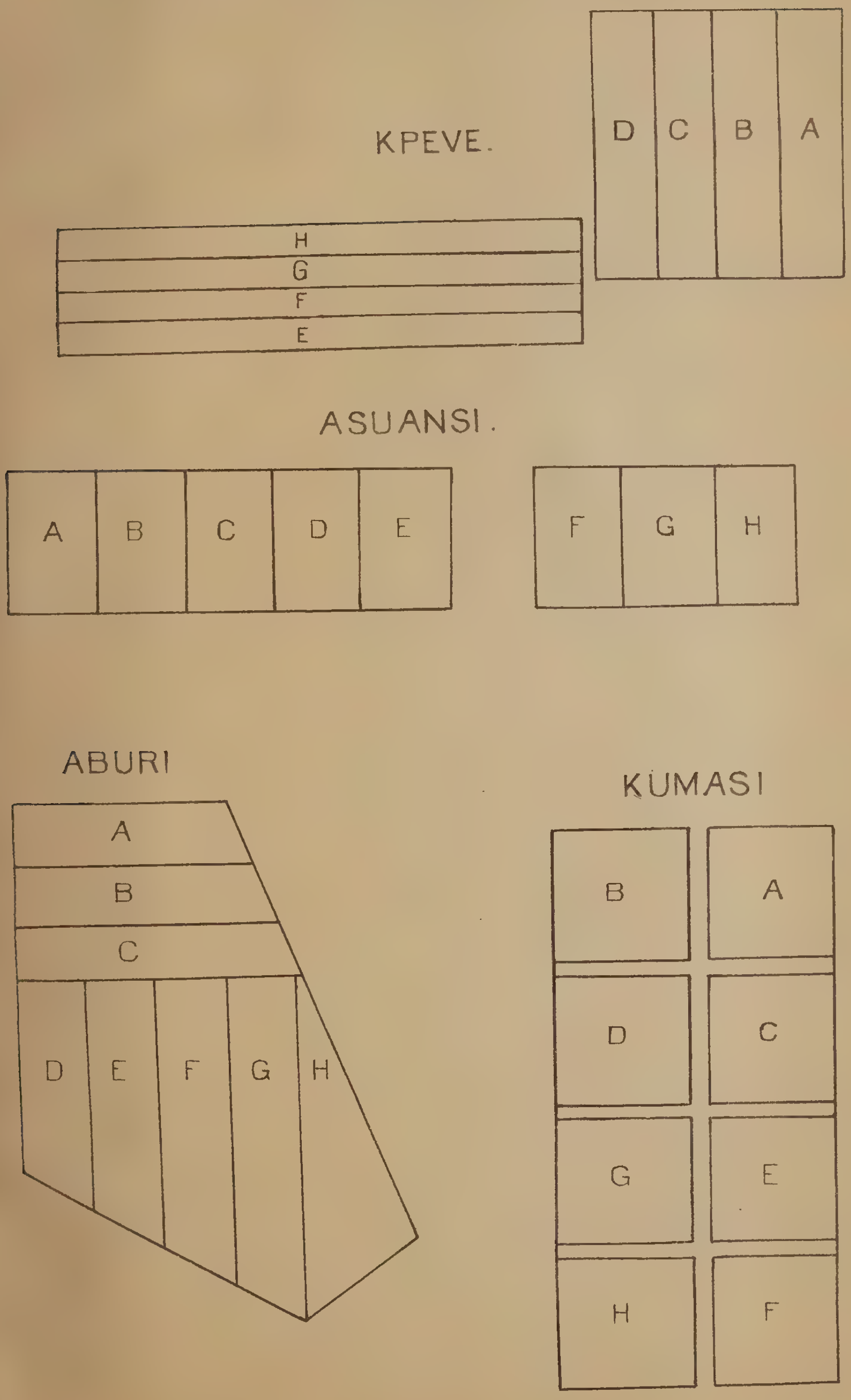
The number of fruiting trees per acre (*b*) is factor which it is safest not to apportion great importance, particularly as the optimum planting distance for cacao on the Gold Coast is not known. Nevertheless it is of interest to note that at Kpeve we have two plots, A and H, each with 48 trees and of the same area and one producing more than twice as many pods as the other. At Asuansi, Plot D, with 82 trees, produced less than half the number of pods reaped from Plot G, which carried only 51 fruiting trees. It is, however, preferred to regard a plot as an area and not as a number of trees.

Whether the age of the field (C) has any stabilising effect is a theory which has some support in the Aburi plots, being much more constant than those of either Kumasi or Asuansi, which are approximately 20 years younger, but Kpeve, the most constant of all, is the youngest.

Plots on Agricultural Stations have received considerable cultivation, and the question of the effect of treatment (*d*) is largely bound up with age if it is assumed—it is thought rightly—that under continuous cultivation of the same kind a field would tend towards equalisation of all parts. It is not thought that the application of mulch and manures in the present trials can have had any marked effect on the number of pods produced in the period under consideration, as the main crop is set in August, during which month they were applied. It is also noticeable that the yield of the control Plot A occupied a precedence in pod productions varying from 1 (Kpeve) to 8 (Aburi), therefore whatever effect recent treatment has had, it has not yet had an appreciable one on initial variation. Admittedly it would have been preferable to have measured the initial variation on all plots before the application of the special treatments, but although this was not done, variation in the first year yields can be credited to initial error and not to the treatment during the year.

PLATE V

RELATIVE POSITION OF PLOTS IN CACAO MANURIAL TRIALS.



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STANDARD CACAO MANURIAL TRIALS.

AREAS AND YIELDS IN PODS ACTUAL AND PER ACRE, AUGUST, 1926, TO JULY, 1927.

STATION.		A.	B.	C.	D.	E.	F.	G.	H.
KPEVE	Area and No. of Trees Fruiting	¼ acre 48	¼ acre 62	¼ acre 56	¼ acre 64	¼ acre 55	¼ acre 55	¼ acre 54	¼ acre 48
	Actual Yield	4,921	4,467	3,473	4,047	3,279	3,458	3,439	2,542
	Yield per Acre	19,684	17,868	13,892	16,188	13,116	13,832	13,756	10,168
ASUANSI	Area and No. of Trees Fruiting	¼ acre 63	¼ acre 64	¼ acre 76	¼ acre 82	¼ acre 63	¼ acre 55	¼ acre 51	¼ acre 67
	Actual Yield	1,456	2,048	2,128	1,081	1,386	1,634	2,252	1,308
	Yield per Acre	5,824	8,192	8,512	4,324	5,544	6,536	9,008	5,232
ABURI	Area and No. of Trees Fruiting	·27 acre 30	·31 acre 42	·30 acre 41	·20 acre 28	·25 acre 32	·23 acre 35	·24 acre 32	·26 acre 39
	Actual Yield	2,472	3,398	3,078	2,667	3,547	3,475	3,895	3,970
	Yield per Acre	9,163	10,961	10,260	13,335	14,188	15,109	16,229	15,269
KUMASI	Area and No. of Trees Fruiting	⅙ acre 36	⅙ acre 33	⅙ acre 32	⅙ acre 33	⅙ acre 33	⅙ acre 33	⅙ acre 31	⅙ acre 36
	Actual Yield	1,886	1,706	712	1,042	2,055	865	2,274	2,050
	Yield per Acre	11,316	10,236	4,272	6,252	12,330	5,190	13,644	12,300

The overwhelming amount of initial error in this trial due to factors outside the control of the experimenter, indicates that trials such as these are necessarily largely confined to a comparison of the improvement or otherwise in each plot over a period of years and that initial error, although approximately measurable, is sufficient to render these comparisons of little value unless made over a considerable period of years. Striking proof of this is given in the Aburi plots, where individual yields of all trees on the plots have been recorded since the year 1914. Figures closely approximate to the yields are given below. They are not absolutely accurate, as it has been necessary to exclude the yields of 13 trees, now dead, the positions of which cannot, with certainty, be determined. It is not considered, however, that the excluded figures affect the issue.

Approximate annual yields in pods:—

ABURI. (FIELD CONSIDERED AS 8 PLOTS.)

Year.	A.	B.	C.	D.	E.	F.	G.	H.
1914	3,170	2,247	2,957	3,382	3,725	4,235	3,851	3,585
1915	2,070	1,803	1,266	3,490	2,351	1,728	1,948	2,179
1916	3,353	2,592	3,320	2,259	3,783	4,407	4,092	4,222
1917	2,089	1,970	2,249	3,072	3,407	3,190	2,949	3,555
1918	3,789	3,279	3,627	3,598	3,615	4,471	4,309	4,912
1919	2,363	2,184	2,431	4,033	4,377	4,601	3,147	3,360
1920	1,382	1,635	1,653	3,487	2,044	2,142	3,055	2,924
1921	1,855	2,777	3,273	3,288	3,532	4,177	2,998	1,752
1922	1,711	2,381	3,311	1,886	2,819	3,651	3,431	2,717
1923	1,090	2,292	2,600	2,561	2,620	2,511	2,398	2,514
1924	1,330	2,845	3,031	2,886	3,882	3,224	2,921	2,824
1925	1,689	2,508	3,156	1,261	3,527	3,116	3,582	3,400
1926	2,532	3,828	3,231	3,250	3,218	3,413	3,458	4,284
Totals ..	28,423	32,341	36,105	38,453	42,900	44,866	42,139	42,228
Av. dev. from Mean ..	30·1%	17·9%	20·4%	20·5%	16·1%	21·5%	15·6%	21·7%

The following table shows the deviation of the 1926-1927 yield from the mean annual yield.

Plot.	Mean Annual Yield (13 Years).	Yield August, 1926, to July, 1927.	Average Deviation from Mean.
A.	8,041	9,163	13·9%
B.	8,027	10,961	36·6%
C.	9,256	10,260	10·8%
D.	14,790	13,335	9·8%
E.	13,200	14,188	7·5%
F.	15,004	15,109	0·7%
G.	13,505	16,229	20·2%
H.	12,492	15,269	22·2%

It will be seen that in two cases do the 1926-1927 yields deviate to a greater extent from the mean than the average deviation over 13 years. (Plots B and G), one is mulched (G) and one unmulched (B), and the manurial treatment of each is different. The deviations cannot, therefore, be regarded as an effect of treatment.

PAPER No. XII.

CORRELATION BETWEEN RAINFALL AND CACAO YIELDS IN THE GOLD COAST, WITH SPECIAL REFERENCE TO EFFECT OF APRIL RAINS ON THE FOLLOWING CACAO CROP.

BY W. T. O. MAIDMENT.

The figures of rainfall and cacao yields are taken from three stations in different localities on the Gold Coast, namely, Aburi, Asuansi and Kumasi, and graphs drawn showing the monthly cacao crops and monthly rainfall from 1920-1925. The variety of cacao in each case is Forastero Amelonado.

There is a distinct parallelism between the monthly rainfall and the monthly crop in each of the three graphs, and if we take the crop graph and move it back until the July crop is over the April rain, and the August crop over the May rain, and so on throughout the year, this fact is brought out more clearly, as the highest points of each curve tend to come together.

Observation of the three appended graphs shows that there is some correlation between the rainfall and the cacao crop. (See Plates VI, VII and VIII.)

PHYSIOLOGY OF FLOWER PRODUCTION.

To assist in making accurate crop forecasts of the probable time and length of harvesting of the cacao crop, the writer puts forward the following theory, which has been suggested from observations of the graph.

In the month of April the majority of the flowers for the main crop are forming and the fruit setting. This is due to a physiological phenomenon on the part of the plant.

To make this point clear, it is necessary to explain what it is that causes a tree to stop producing new shoots and leaves and to begin to produce flowers and fruits. Plant physiologists seem to be of the opinion that it is largely determined by the relative amounts of carbohydrates and nitrogenous substances,* and it is interesting to see whether this view can be applied to the question at present under consideration. The vegetative growth is dependent on the nitrogen supply, which is obtained from the soil, while the carbohydrate supply is dependent on vegetative growth, since it is the function of leaves to produce carbohydrates. At the beginning of a new growing season (which in the case of cacao may be taken to be at the beginning of the first rains, say the end of February), vegetative growth proceeds apace owing to a supply of nitrogen being rendered available to the plant by the rain, due to the renewed activity of the nitrifying bacteria of the soil. At this stage the ratio of carbohydrates to nitrogen in the plant is low, but later, owing to the activity of the newly formed tissues, the ratio of carbohydrates to nitrogen gradually increases, and when a certain

* Some physiological aspects of pruning by E. C. Cheeseman, B.Sc., "The Tropical Agriculturalist," Vol. LXV., No. 5, November, 1925.

point is reached, the behaviour of the growing point is changed over, and flowers are produced. The important point is that the flowers will not be produced until there is enough reserve material in the plant for the production of flowers and fruit.

In an early year the crop definitely commences in August and in a late year does not begin until September.

EFFECT OF APRIL RAINS.

Inspection of the Aburi and Kumasi graphs will show that when the rainfall for April is over six inches, the crop in that year is late and is over by the end of the January. On the other hand, when the April rainfall is less than six inches, the crop in that year is early, and is not over until the end of February. The exceptions to this is in the years 1921 at Kumasi and 1923 at Aburi. The exception in the Kumasi record will be dealt with later.

A comparatively heavy rain in April will induce extra vegetative growth, which may be enough to upset the carbohydrate-nitrogen ratio by a rapid increase in nitrogen content. If this were the case the formation of flowers would be temporarily checked by the extra vegetative growth. When the balance between the carbohydrates and nitrogen is restored, flowering will rapidly proceed, as a result of renewed supply of food material. This may explain the lateness and short duration of the crop.

On the other hand, when the April rains are below this six inches turning-point, there is no extra stimulant given to vegetative growth, and the carbohydrate-nitrogen ratio remains undisturbed. The flowering continues evenly over a longer period and so the crop tends to be earlier and to persist over a longer period.

Inspection of the different graphs show that Aburi and Kumasi, having the same general physical conditions, appear to conform to this theory. This is not so in the case of Asuansi, where there is very little difference in any year between the time the crop commences and the time it finishes. From this it would appear that the theory regarding the amount of April rainfall would only apply to districts of the same physical and climatic conditions as at Kumasi and Aburi, since the general physical conditions obtaining at Asuansi are considerably different from the two former places.

The 1921 crop at Kumasi and the 1923 crop at Aburi would seem to discount the above theory, but in the case of Kumasi this may be explained when the daily rainfall for April is seen. Here most of the rain fell after the 13th of the month, by which time some of the fruit would have set, consequently the crop ranked as an early one.

The above theory is put forward as a possible guide for forecasting the incidence and duration of the cacao crop in those districts similar to Kumasi and Aburi in general physical and climate conditions. If, however, the distribution of rain in any one year is abnormal, as in 1927, when in Kumasi there was a marked shortage of rain from May to September, it would seem probable that the theory would not apply.

MONTHLY PERCENTAGES OF RAINFALL AND CACAO YIELDS ON KUMASI EXPERIMENT STATION.

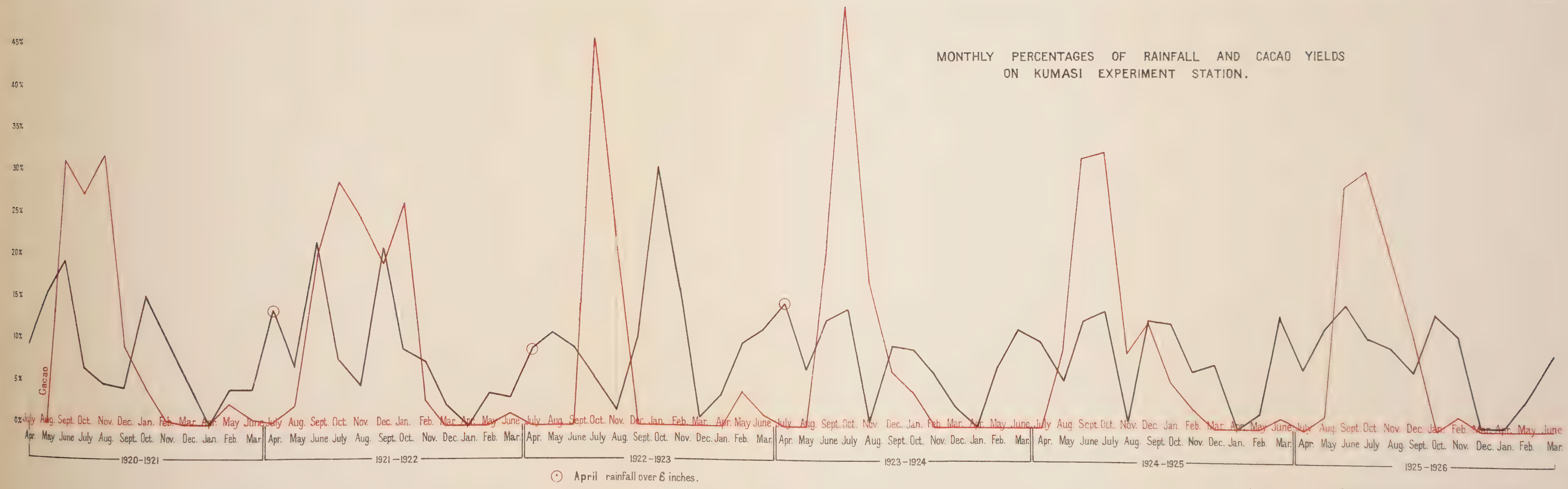

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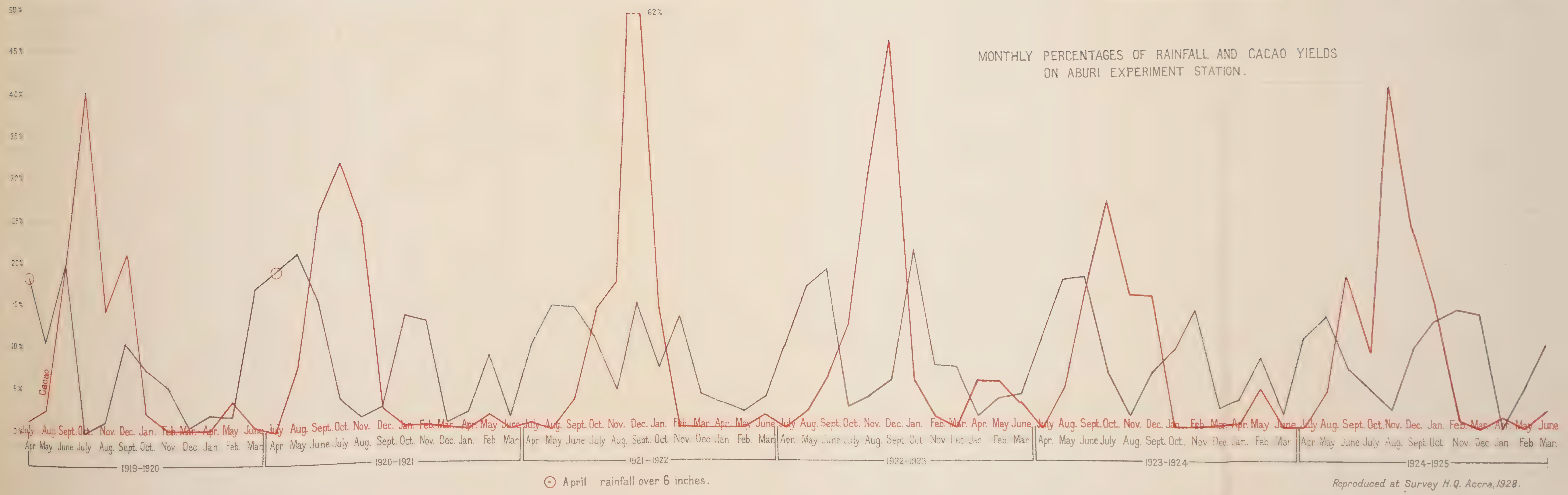
Plate Nº VII

MONTHLY PERCENTAGES OF RAINFALL AND CACAO YIELDS
ON ASUANSI EXPERIMENT STATION

Reproduced at Survey H.Q. Accra 1928.

Plate Nº VIII



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PAPER No. XIII.

THE RELATION BETWEEN DISEASED CUSHIONS AND THE SEASONAL OUTBREAK OF "BLACK POD" DISEASE OF CACAO.

By H. A. DADE.

Illustrations in colour by Lynn Dade.

The disease of the bark known as "canker" does not apparently attain, in the Gold Coast, to the same serious proportions as in other cacao producing countries. It is, however, sufficiently widespread to be well known, and recent observations have shown that it is of far more common occurrence, in an inconspicuous form, than was previously known, and that it therefore bears a much more important relation to the incidence of cacao pod disease than was previously suspected.

It will be superfluous to refer in detail here to the work of well-known plant pathologists who have described canker and its cause in other countries. All agriculturists who work with cacao will be familiar with their work. J. B. Rorer, working in Trinidad, first definitely showed that canker was due to *Phytophthora Faberi*, Maub., the fungus which also causes the principal pod disease. A recent detailed account of cacao canker will be found in Nowell's "Diseases of Crop Plants in the Lesser Antilles." It was, of course, known that cushions became infected from diseased pods, and *vice versa*.

The purpose of this note is to describe in some detail the form of canker most commonly found in the Gold Coast.

In previous work (See Bulletin No. 6 of this Department) it was found that cases of "black pod" disease, caused by *P. Faberi*, occur in rather definite proportions in different regions of the pod—*i.e.*, about two-thirds of the infections occur in the proximal region, one-quarter in the lateral, and the remainder in the distal region. The factors responsible for this were discussed, but it was shown that in some cases proximal infections were derived from previously diseased cushions, and were not external in origin, though for what proportion of the proximal infections diseased cushions were responsible was not known. A study of the heaps of discarded husks which are left by farmers in their farms, and which had formerly been regarded as responsible for carrying over disease from one year to another, produced evidence that some other means of "over-wintering" must be chiefly responsible, and there was, moreover, some evidence that diseased cushions provided this means.

In 1927 a closer study of this aspect of pod disease was made. At the beginning of the season a survey of farms in Akyem and Kwahu was carried out, and it was found that the great majority of the proximal—and indeed of all—"black pod" infections

which had occurred by then were definitely associated with cushions in which there was deeply seated disease. All stages of infection were seen, including cases in which infection had not yet actually reached the pod, but was travelling down the peduncle.

Small blocks of infected tissue, removed from the deeper regions of cushions by means of sterile knives, produced cultures of *P. Faberi* on corn meal agar. These cultures were more than usually vigorous, and produced a rapid rot on cacao pods within two days after inoculation.

There is therefore no doubt that *P. Faberi* can pass the harmattan* in cushions. The majority, if not all, of the earliest pod infections have their origin in diseased cushions, and there seems to be no doubt that this is the principal, as it is certainly the most effective, means of production of the seasonal activity of *P. Faberi* as a pod pathogen.

A close examination of cacao growing in Aburi agricultural station revealed no diseased cushions and no infection by *P. Faberi* as late as September. On this station all diseased pods are systematically removed as soon as they are observed, and no doubt this practice has been the means of preventing cushions from becoming infected. The infections which take place there every year—very few as compared with those in native farms—are external and probably are derived from neighbouring farms.

Dissection of diseased cushions shows that the adjacent bark is more or less involved in typical bark canker, and that the infected portions of the cushions are continuous with the cankers.

In the tissues of the peduncle and the summit of the cushion some assimilatory tissue is present, and its pale green ground colour affects the appearance of the areas recently involved in active infection. Here the discoloured tissues are of a water-soaked greyish-green colour, with reddish edges, and traversed by reddish lines. They become claret coloured with age, then black and dry. On exposure to the air the colour rapidly changes to a dull brown, but the original colour may be preserved for a short time, for examination, by immersion in water. When the peduncular trace is affected, as frequently occurs, it assumes at first a pale brown colour, and later becomes black.

The general appearance of diseased cushions is indicated by figures 3-8 in Plate IX.

From the cushion infection proceeds into the surrounding bark. It extends only for a short distance laterally or vertically upwards, but spreads principally vertically downwards for a distance of up to five or six inches, usually two or three inches. (See figures 1-3 in Plate X.)

In previous descriptions of canker the claret colour of infected bark has been emphasized. In the cases studied by the present author the claret colour was assumed only with age. Attempts to obtain cultures of *P. Faberi* from claret coloured tissues have failed. In the tissue of active cankers the colour of the freshly

* N.B.—The harmattan is the dry wind which blows from the Sahara to the South during December and January. The word is used here to indicate the season.—*Editor.*

PLATE IX

DISEASED CUSHIONS OF CACAO TREES.

Figs. 1, 2.—Infection of pods from diseased cushions. A—Diseased tissue of peduncle containing active mycelium. B—Site of first appearance of disease on surface of pod. C—Opposite side of pod reached by lateral circumferential spread. X—"Basal part" of peduncle.

Figs. 3-8.—Appearance of diseased cushions after removal of summit. A—Tissue containing active mycelium. B—Older part of infection.

PLATE X.

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SECTIONS OF DISEASED CUSHIONS.

Figs. 1-3.—Bark cankers continuous with diseased cushions. Outer bark removed in 1 and 2, partly removed in 3. A—Recently invaded tissue containing active mycelium. B—Older infected tissue. T—Peduncular trace.

Figs. 4, 5.—Small cankers in bark caused by contact between shoulder of diseased pod and trunk. Outer bark removed.

exposed diseased bark is a pale maroon with brighter reddish brown edges. Close examination shows that the general colour is largely due to the numerous wavy red lines which mark the limits of growth periods of the fungus. The true ground colour is difficult to describe and to reproduce in illustrations. The whole area is water soaked, which deadens and obscures colour, and the appearance of the tissue between the darker zone lines is a sort of very pale pinkish fawn. After a short exposure to air the whole of the diseased surface darkens rapidly to a deep claret colour, and the network of fine zone lines disappears.

The downward extension of the canker is narrow, but penetrates through the bark and blackens the wood.

Small cankers often occur in bark just below the cushions where diseased pods growing from the cushions are in contact with the trunk. (Figures 4, 5, Plate X.) These small cankers do not normally spread, and have not been found to infect cushions above. Normal extension of canker growth seems to be vertically downwards. It is possible that some cases of lateral infection of pods may take place from such cankers in succeeding years.

In a few cases, cushions were found to be infected from previously infected cushions immediately above them.

Pod infection due to diseased cushions cannot be readily diagnosed by inspection. Active cankers cannot be found by examining the outer bark, which shows no trace of their existence until they are old, when the bark cracks and exudation of sap occurs before the final desiccation. The existence of diseased cushions can, however, be discovered, when a proximally infected pod is seen, by lightly scraping the peduncle with a knife or the finger nail. The brown cuticularised layer is thin and easily removed, and in a healthy case bright green assimilatory tissue is exposed. On the summit of the cushion the colour of the exposed surface is green to cream. It may be necessary, in a fresh infection, to examine the complete circumference of the peduncle, but it is usually sufficient to scrape it on the side where the pod infection has progressed most.

If the pod has been infected externally, the peduncle shows no discolouration unless the infection is an old one and the pod is completely involved. Even then discolouration frequently does not proceed into what Van Hall calls the "basal part" of the peduncle—*i.e.*, the part which forms the cushion of the following year. (Figure 1, x, Plate IX.) When the basal part is invaded the cushion is definitely infected.

In the case of infection proceeding *from* the cushion removal of the cuticle of the peduncle shows a greyish green area with reddish edges, traversed by red lines, and this may be traced by further scraping into the cushion. In older infections the peduncle is dry and brown.

(The use of stainless steel scalpels in the critical dissection of cacao tissues is advantageous.)

Infection usually travels down one side of the peduncle—that side adjacent to the diseased part of the cushion. The fungus

reaches the pod at the insertion of the peduncle, and proceeds to the surface of the shoulder of the pod. It spreads more rapidly laterally than vertically, and quickly reaches the opposite side of the pod. (See figure 1 in Plate IX.) The five vascular strands which lie in the axis of the pod are very soon affected and blackened. Infection continues to spread more rapidly through the cortical tissue, however, and not via the vascular system.

In normally healthy trees cankers found in connection with diseased cushions do not attain to great dimensions. Five or six inches is about their maximum length. Extreme cases of very serious bark injury are not very common in the Gold Coast. Occasionally farms are found where serious cankers exist and where large areas of bark are involved, but all such cases as have been seen have been associated with environmental conditions unfavourable to the constitution of the host. It is, in fact, probable that the relative unimportance of bark canker, as far as injury to the bark is concerned, in the Gold Coast as compared with other countries, may be due to the remarkably favourable conditions for cacao culture which exist here.

In the areas in which diseased cushions were studied in 1927, environmental conditions are such as favour a large incidence of pod disease, and are also favourable for cushion and bark infection, but the trees are in normal health. Under such conditions recovery is the rule. The complete history of the cushion infections is not definitely known—it is not possible to investigate the course of the attack and at the same time to preserve the case, as no external symptoms are demonstrated until the advance stage ensues. But so far as can be made out, infection normally takes place from a diseased pod, via the peduncle; thence it spreads to the bark and extends below the cushion for five or six inches. The active stage probably continues over a period of two or three years, during which time pods borne on the cushion are infected. Finally, the cushion becomes so completely involved that fruit production ceases. Extension of the adjacent bark canker ceases at about the same time, or perhaps a year later. The dead bark rots away, and is often removed by ants, which make temporary shelters in the cavities thus formed. The outer bark cracks, dries and curls inwards into the cavity. The cushion also decays and is represented by a shell of dried outer bark and fragments of peduncles. (Figure 1 in Plate XI.) Cambial regeneration begins immediately the canker ceases to spread, and cambial folds roll laterally inwards below the dead outer bark, which is forced outwards. Removal of this outer bark from what appears to be a serious lesion now displays a completely or almost completely renewed bark. (Figure 2 in Plate XI.) Recovery seems to be rapid.

Single trees may be seen with dozens of cankers in all stages, from primary infections to complete recoveries. In other cases, trees which do not fruit in a particular season may be found to be in a state where every cushion has reached the stage of destruction, and cambial activity apparently absorbs the resources of the tree. Such cases are rare.

PLATE XI.

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CANKERED CACAO TREES.

Fig. 1.—External appearance of cushion which has been destroyed, with bark canker below. Bark dry, discoloured and cracked.

Fig. 2.—Recovery. Part of old outer bark removed to show new bark covering old canker.

PAPER No. XIV.

A COMPARISON OF THE PATHOGENICITY OF VARIOUS STRAINS OF *PHYTOPHTHORA FABERI*, MAUBL., ON CACAO PODS, ETC., IN THE GOLD COAST.

BY H. A. DADE.

This work was undertaken at the request of Professor S. F. Ashby, of the Imperial Bureau of Mycology, at whose disposal the information obtained has been placed.

Many strains of *Phytophthora Faberi* exist, causing diseases in a wide range of tropical crops, and the affinity of these several strains is not yet clear. Sexual reproduction takes place only when certain strains are grown in mixed culture with other strains or with other species of Phytophthora, as was first shown by Ashby ("Oospores in cultures of *P. Faberi*," Kew Bull., p. 257, 1922).

The present work provides information which may assist in throwing light on the affinities of the various parasitic strains in question, by demonstrating their relative pathogenicity on cacao pods.

The strains used, the first nine of which were supplied by Professor Ashby, were:—

1. Coconut bud rot, Jamaica.
2. Palm, India, sent from Pusa to the Department of Agriculture, Federated Malay States, and thence to Imperial Bureau of Mycology in 1926
3. Hevea black thread, Federated Malay State, sent to Imperial Bureau of Mycology in 1926 by A. Thompson.
4. Sea Island Cotton boll-rot, St. Vincent (Ashby).
5. Cacao pod-rot, Trinidad.
6. Mimusops fruit rot (Gold Coast) sent to Imperial Bureau of Mycology in 1924 by the present writer.
7. Cacao pod-rot, Philippines (Reinking's) strain, obtained by Imperial Bureau of Mycology from the Bearn Collection, Holland.
8. Citrus blight, Philippines (Ocfemia).
9. Cacao pod-rot, Gold Coast, sent to Imperial Bureau of Mycology in 1925.
10. Cacao pod-rot, fresh isolation, Gold Coast.

Unfortunately the numbers of infections studied were small owing to the limitations of laboratory facilities, but the results show at least some definite facts.

Twenty Criollo and twenty Amelonado pods were used in artificial inoculations with each strain of *P. Faberi*. Half of these were wounded with a knife point, the other half were intact. The pods were kept in a saturated atmosphere in desiccators. Temperature varied between 75° and 82° C.

Results are shown in the table.

Strains 3, 4 and 8 are evidently not able to parasitize cacao pods.

Strain 6, when freshly isolated in the Gold Coast by the writer in 1924, was a rather feeble wound parasite. After being in artificial culture since 1924, it appears to have lost its pathogenicity. (This strain was found causing a fruit fall and rot in Mimusops (Elengi?) at Aburi).

Strains 1 and 2 are rather doubtful wound parasites.

Strain 7 was received as Reinking's strain of *P. Faberi*, causing cacao pod rot in the Philippines. If its source is authentic it would appear to be an abnormal culture, for it is evidently only very feebly parasitic, and after such a long delay in growth may have been only growing in necrotic tissue.

Strain 5, the Trinidad cacao pod organism, is undoubtedly identical with the Gold Coast form.

The Gold Coast culture (strain 9) was sent to Imperial Bureau of Mycology in 1925, and has been in artificial culture since then. It was distinctly less virulent than the fresh isolation (10).

The present writer obtained oospores by growing strains 6 and 9 on cacao pods, and therefore attempts to obtain oospores on Hevea pods and cotton bolls were made as follows:—

Hevea.

Strain 3 *alone.*—(Check) 6 pods were inoculated.

Discolouration began after 3 days in each case.

Sporulation in all on the fifth day.

Strains 3 *and* 2, 3 *and* 5, *and* 3 *and* 9.—Six pods were used in each double inoculation.

Strains 2, 5 and 9 grew much more quickly than 3, which was completely overgrown, strain 5 being the most rapid in spread. No oospores were found.

Cotton Bolls.

The only Egyptian cotton available was a bastard strain originally imported into Togoland by the German authorities.

Strain 4 *alone.*—(Check) 12 bolls were inoculated.

Discolouration began after two days and spread rapidly.

Aerial mycelium was produced and sporulation began on the third day.

Strains 4 *and* 2, 4 *and* 5, *and* 4 *and* 9.—12 bolls were used in each double inoculation. All were discoloured after two days, and all were in an advanced stage of decay after five days. No oospores were found.

Strain.	AMELONADO.		CRIOLLO.	
	Wounded.	Unwounded.	Wounded.	Unwounded.
1. Jamaica Coconut Bud-rot.	1/5 + ve. Discolouration began after 2 days, stain 1″ diam. after 6 days. Pods completely involved after 10 days. Chlamydospores after 8 days on ærial mycelium. Before this, only sporangia.	All —ve	1/5 + ve. As for Amelonado.	All —ve.
2. Palm, India ..	2/5 + ve. Slight discolouration after 7 days, reaching diameter of 2″ after 14 days. Scanty sporulation. Swamped by secondary contaminations of saprophytes.	All —ve	4/5 + ve. As for Amelonado.	All —ve.
3. Hevea, F.M.S. Black Thread.	—— All —ve ..	10 days after inoculation.		
4. Cotton Boll-rot, St. Vincent.	—— All —ve ..	16 days after inoculation.		
5. Cacao Pod-rot, Trinidad.	5/5 + ve. Discolouration began 2 days after inoculation. Pods completely involved after 7 days. Sporangia and chlamydospores.	1/5 + ve. Discolouration 2″ in diameter after 7 days. Pod completely involved after 12 days.	5/5 + ve. As for Amelonado.	2/5 + ve. Discolouration 1″ and $2\frac{1}{2}$″ diam. after 7 days. Pods completely involved after 12 days.

Strain.	AMELONADO.		CRIOLLO.	
	Wounded.	Unwounded.	Wounded.	Unwounded.
6. Mimusops, Gold Coast	All —ve ..	12 days after inoculation.		
7. Philippines, Cacao (Reinking).	1/5 + ve. After 10 days. Sporangia and chlamydospores formed.	All —ve	All —ve	1/5 + ve. After 10 days Sporangia and chlamydospores formed.
8. Philippines, Citrus (Ocfemia).	All —ve ..	15 days after inoculation.		
9. Gold Coast, Cacao (I.B.M.).	5/5 + ve. Discolouration began 2 days after inoculation. Pods completely involved after 9 days. Sporangia and chlamydospores.	2/5 + ve. Discolouration began after 8 days. Pods completely involved after 16 days. Sporangia and chlamydospores.	5/5 + ve. As for Amelonado.	All —ve.
10. Gold Coast, Cacao (Fresh Isolation).	5/5 + ve. Discolouration began 2 days after inoculation. Pods completely involved after 7 days. Sporangia and chlamydospores.	4/5 + ve. In 3 pods discolouration after 6 days. Pods completely involved after 11 days. In 1 pod discolouration after 8 days, whole pod involved after 13 days.	5/5 + ve. As for Amelonado.	4/5 + ve. In 2 pods discolouration after 5 days. Pods completely involved after 10 days. In 2 others discolouraation after 8 days, completely involved after 13 days.

PAPER No. XV.

DISSEMINATION OF CACAO POD DISEASES BY INVERTEBRATES.

By H. A. DADE.

Early in the 1927 season a rather unusually large number of cases of "Mealy Pod" were observed on some trees in a cacao plot in the Aburi agricultural station. Distribution through the plot was very uneven, and could not be correlated with the usual determining factors. The few particular trees affected showed a very high percentage—25 to 68—of infections.

Close observation showed that these trees were infested by ants, which were eating the conidia of *Trachysphæra fructigena*, Bunt. and Tabor, and in some cases carrying away masses of conidia. Two species were found behaving thus—(i) a small brown species, which was also herding coccids, and living in temporary shelters in crevices or under leaves at the base of the tree; (ii) a larger black species. The latter also damages pods by removing the epidermis, which is used in the building of large arboreal "carton" nests. They have not yet been identified, but belong probably to the genus *Crematogaster*. (Some members of this genus cultivate fungus gardens, but these have not been found in the case of the two species under discussion.)

The transportation of spores by ants forms an effective means of dissemination of pod disease, and when damage to the pods also takes place infection is facilitated. The debris which ants eject from their mouths is known to contain fungus spores which have been removed from their limbs in the process of cleaning, which is performed by the mouth.

A small flat snail is rather common in cacao farms and has been seen feeding on spore masses of *T. fructigena*. One of these snails was fed on a "mealy pod" in the laboratory, and the excrement was found to contain large numbers of viable spores, which germinated in hanging drop cultures, and which produced mealy pod disease when inoculated into pods.

These two cases serve to indicate the large though inconspicuous part which insects and other small invertebrates undoubtedly play in the transmission of pod diseases.

PAPER No. XVI.

THE RED BANDED CACAO THRIPS, HELIOTHRIPS RUBROCINCTUS, GIARD.

By G. S. COTTERELL.

The red banded cacao thrips, *Heliothrips rubrocinctus*, Giard, has been known to attack cacao in the Gold Coast for a considerable time. It has a large number of other food-plants and no doubt occurred on these before cacao was introduced.

The adult is a small black suctorial insect about one-sixteenth of an inch in length with two pairs of narrow wings fringed with hairs. The wings are carried folded up over the abdomen when not in use. (Plate XII, figs. 1 and 2.)

The nymphs are yellow with a red band extending across the dorsal surface of the first two abdominal segments. Except in the two final nymphal stages six long black hairs project from the final abdominal segment and these support a drop of fluid which consists of excrement which is carried about by the nymph (Plate XII, figs. 4 and 6) until surface tension is overcome and the drop falls on the leaf or pod forming a brown blotch when dry.

Damage is caused by the nymphs and adults sucking the lower surface of the leaf or surface of developing pods. The epidermal cells are broken down and in severe cases of leaf damage this is followed by general necrosis of the attacked area and subsequent abscission.

Leaf damage is much more serious on young trees than established trees.

H. rubrocinctus is known as a pest in all cacao-producing countries, and in some places as a pest of major importance. In San Thomé enormous damage is attributed to this insect [ref. Patterson, in Thrips in San Thomé (1)]. In the Gold Coast it cannot at present be called a major pest, but the conditions favourable to the development of this pest are becoming more and more common and it is possible that it may become of major importance in the near future. In this country, attack is found to occur under three bad cultural conditions which can all be correlated with faulty water relations between plant and soil, otherwise conditions that are not favourable to the growth of cacao. These three conditions are (i) low or irregular humidity, due to indiscriminate deforestation, (ii) exposure of plant and soil to sun and wind, *i.e.*, absence of overhead and lateral shade, (iii) soil of a low water retaining power. It is only in areas where the above conditions exist that Thrips attack is found.

PLATE XII.

Fig. 1.

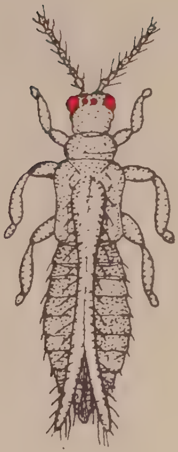

Fig. 2.

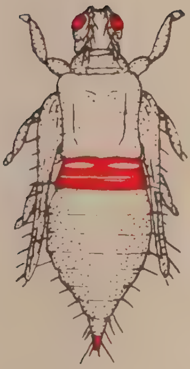

Fig. 3.

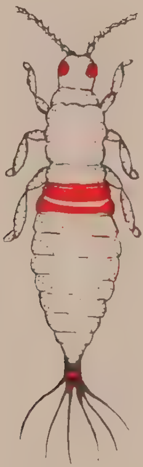

Fig. 4.

Fig. 5.

Fig. 6.

The Red Banded Cacao Thrips. (Heliothrips rubrocinctus.)

Figs. 1 & 2. Adult stage. Fig. 3. Pupal stage.
Figs. 5 & 6. Nymphal stage.

Both the under side of the foliage and the surface of the pods are attacked. The former is the less serious of the two as only the outer skin of the pericarp is effected so that the pod develops normally. Pods are not attacked until within a few weeks of maturity. It is difficult to ascertain when attacked pods are mature as the whole surface becomes rust coloured. By scraping the epidermis of an attacked pod the familiar yellow colouring indicating maturity can be observed. Naturally, therefore, a number of attacked pods are reaped either before or too long after maturity resulting in a lowering in quality of the ultimate product owing to the mixing of immature or over-mature beans.

Damage to foliage is much more serious, as attacked leaves are as a general rule abscissed, resulting, in severe cases, in complete defoliation. Attack is confined to the under surface of the leaves. Occasionally, succulent leaves are attacked, but normally, attack is confined to the older leaves.

Abscission followed by die-back resulting from Thrips attack also follows purely physiological conditions, chiefly bad water relations, that are unfavourable to the growth of cacao. In the past, a very large amount of this die-back has been credited to Thrips. This is not the case. For this reason, as far as this country is concerned, Thrips can be classed for the present as a minor pest, as it is entirely secondary to bad cultural conditions. Where Thrips is found as a pest, attacks are found to be periodic corresponding with conditions where physiological die-back is expected to occur.

These conditions consist of abnormal periods of drought or heavy rainfall in areas where shade and soil conditions are not suited to the growth of cacao. In the Gold Coast at the present time all years are climatically abnormal when compared with the conditions under which cacao was originally established.

H. rubrocinctus has a wide range of food plants in this country. Among those recorded so far are:—

Cola acuminata.
Mango. (*Mangifera indica.*)
Guava. (*Psidium guayava.*)
Avocado. (*Persea gratissima.*)
Acalypha sp.
Terminalia sp.

There are many others in addition. In San Thomé *Claoxylon molleri Copaifera mopane*, *Manihot utilissima*, *Pseudospondias microcarpa*, *Psidium pomiferum*, and *Urophyllum insulare* are listed as food plants by De Seabre (2).

In 1925 the life history of *H. rubrocinctus* was roughly worked out at Asamankese in Akim-Abuakwa when the writer was working on other pests of cacao. Difficulty was found in improvising a suitable type of cage in which the insects could be confined and the various stages observed. It was found necessary to cage the insects on the plant in the field. Eventually, a cage was made consisting of a cover of an entomological pill box with the glass

removed and replaced by a double layer of fine cotton gauze. An inside wall of cardboard was made and the space between the two walls packed with cotton wool so that, when clamped to the under surface of a cacao leaf, no space was left between the leaf veins through which the insects could escape. A number of these cages were put out and were found to be more or less satisfactory, but even so a large number of insects escaped. Twenty to thirty adult Thrips were confined in each of these cages and left one day, after which they were removed. It was thus possible to ascertain roughly the incubation period of the egg and length of the subsequent stages. The incubation period was found to average one to three days. Reyne (3) states that in Surinam he found the incubation period to be as long as 10 to 13 days at 68°-86° F. Urich (4) gives the incubation period in Grenada as from three to four days. It is probable that the incubation period varies considerably in different parts of the world and at different periods of the year. The eggs are deposited singly in the under surface of the leaves usually adjacent to a leaf vein and also in pods and covered with a drop of excrement. They are bean-shaped and translucent. The nymphal life was found to vary from twelve to thirteen days during which time there are four moults. The feeding period averages seven days, during which there are two moults, the second being followed by the so-called pre-pupal stage. (Plate XII, fig. 5.)

During the feeding period the nymph is exceedingly active, and is characterised by six long black spines that project from the final abdominal segment. These spines support a drop of excrement which periodically falls off forming brown blotches on the pod or leaf. In this stage the abdomen is curled upwards at the tip so that the drop is carried over the abdomen. In the pre-pupal period these hairs, and therefore drop, are missing. Feeding ceases and the nymphs are comparatively inactive. The wing lobes have commenced to appear as two extensions from the thoracic segments. This stage lasts approximately three days and the nymphs tend to congregate together usually at the proximal end of the leaf. Another moult occurs and the so-called pre-pupal stage is reached. (Plate XII, fig. 4.) In this stage the nymphs are inactive, but move if disturbed. The pupal period is characterised by a change in colour, becoming more opaque due to the development of fat. It can be distinguished from the previous stage by the larger wing lobes and by the antennæ, which in this stage turn back over the head whereas in the previous stage they project forward.

The pupal stage averages three days in length when a final moult occurs and the winged adult is produced. In Grenada, Urich (4) states that the feeding period lasts about nine days and the pre-pupal and pupal stages 24 hours and 48 hours respectively. In Surinam, Reyne (3) gives the feeding period as 9 to 10 days, the pre-pupal 24 hours and the pupal two to three days.

At Asamankese all adults examined were found to be females, but no large count was made. The adults are parthenogenetic, but probably a few males are produced occasionally. In Surinam, Reyne (3) states that out of a count of 30,000 only 0.26 per cent. were males. The highest percentage of males was 1.5 per cent. in the case of a severe infestation.

Reyne (3) states that the maximum number of eggs oviposited by one female was 87.

The adult has two pairs of narrow fringed wings and appears to be incapable of long direct flight. Flight consists chiefly of hops from leaf to leaf. Although Thrips are found infesting cacao growing in exposed situations direct sunlight is avoided. This is more marked with nymphs than adults.

Natural enemies of *Heliothrips rubrocinctus* in this country consist of (1) a predaceous Thrips, (2) small spiders, and (3) an internal Hymenopterous parasite. The predaceous Thrips has not yet been determined. Nymphs and adults are occasionally found amongst *Heliothrips* colonies. It is of no importance as a check. Small spiders, which spin their webs over the undersurface of the leaves and live chiefly at the expense of Thrips, appear to form an important check. There appears to be a kind of symbiosis between these spiders and their prey, as the latter invariably collect under these webs presumably for protection from other predators, during the pupal and pre-pupal periods. The effectiveness of these spiders as a control is somewhat neutralised by the fact that a number of adult parasites emerging from parasitised nymphs are undoubtedly caught in the webs and destroyed.

The hymenopterous parasite is exceedingly minute. Emergence takes place from the pre-pupal or pupal stage of the host. Details of this parasite have already been published as far as known by the writer (5) in the 1926 Year Book, pp. 47-48. Parasitism has reached as high as 80 per cent. following periods of heavy infestation.

There is no record of a parasite emerging from the nymphal stages in other countries in which Thrips occurs.

A Scelionid egg parasite, *Baryconus* sp., has been recorded by Bondar (6) in Brazil.

It is possible that the presence of the nymphal parasite in this country is a reason why Thrips is not so prevalent a pest as in other cacao-producing countries.

This parasite may be of considerable use in the Island of San Thomé if it does not already occur there.

According to Reyne (3) natural enemies of Thrips in Surinam include two species of a Chrysopid larvæ and a *Cephalosporium* fungus. Urich (4) states that in Grenada a species of lace-wing fly (Chrysopid) and in Trinidad several species of Reduviid bugs exercise some measure of control, but that these do not confine themselves to Thrips and generally appear after the worst damage has been done. An entomogenous fungus, *Sporotrichum globuliferum*, has been observed to attack Thrips in Barbados, but is stated to be of little use as a control.

As Thrips attack always follows certain cultural conditions that are unfavourable to the growth of cacao, correction of these conditions is obviously the only line of control. These measures therefore are (i) the prevention of indiscriminate deforestation, (ii)

the provision of adequate overhead and lateral protection to farms where these have been removed, and (iii) improvement of soil conditions by draining and manuring if practicable. In a number of areas it is impossible to correct these conditions. However, as these conditions are unfavourable to the growth of cacao, causing physiological die-back, these areas should be abandoned as far as attempting to establish new cacao is concerned. It may be that already established cacao growing in these areas may be doing fairly well having been established under entirely different conditions. In these areas pod damage is the most serious and leaf damage comparatively small. In these cases attack on pods will start up as soon as a hole is made in the overhead shade exposing the soil. Pods on surrounding trees will become heavily infested with Thrips following any abnormal climatic condition. The same will happen when lateral protection is removed. In these cases the protection should be replaced.

In this country, artificial controls such as the use of sprays or dusts are impracticable at any rate as a measure against Thrips. Reyne (6) in Surinam stated that a spray consisting of a wash of 2 per cent. milk of lime in water was effective. Kaolin was found to be more effective, but it is difficult to distinguish between treated and untreated trees. This type of spray is purely protective. While the writer was experimenting with lime-sulphur wash at Asamankese it was found that the deposit of lime and sulphur left on the foliage remained a considerable time and had the effect of keeping Thrips away whilst it was present.

SUMMARY.

1. The Red-banded Cacao Thrips, *Heliothrips rubrocinctus* Giard has been known in the Gold Coast for a considerable time.

2. Damage is caused by the adults and nymphs sucking the under side of the leaves and pods. In the former case, general necrosis of attacked areas follows, and in severe cases the leaf is abscissed.

3. Leaf damage is more serious on young trees.

4. Attack occurs under conditions that are unfavourable for the development of the cacao plant, *i.e.*, bad soil, lack of shade and lateral protection.

5. Damage is found to be secondary, as damage always occurs in areas where physiological die-back is prevalent.

6. A list of the major food plants is given.

7. The eggs are deposited singly in the under side of the leaves and in pods and all subsequent stages are laid on the plant. The incubation period was found to average one to three days.

8. The feeding period averaged seven days, the pre-pupal three days and the pupal period three days.

9. Parthenogenesis occurs. All adults at Asamankese were found to be females. It is possible that occasionally a few males are produced.

10. Natural enemies consist of a predaceous Thrips, small spiders and a Chalcid parasite which emerges from the pre-pupal or pupal stage.

11. Cultural methods of control consist of the correction of the conditions favourable to Thrips attack.

12. Artificial controls are impracticable in this country, but it has been ascertained that the application of a 2 per cent. solution of lime or kaoline acts as a preventative against oviposition.

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PAPER No. XVII.

MINOR PESTS OF CACAO.

BY G. S. COTTERELL.

Sucking Insects.

Details of the life-history and habits of the pests listed below have been worked out in conjunction with investigations into the life-history and habits of *Sahlbergella* spp. at Asamankese in Akim-Abuakwa in 1925.

Helopeltis bergrothi, Reut.

Helopeltis bergrothi, known locally as "Cacao Mosquito," although having no relation to the Culicidæ, is a Capsid bug which damages cacao by puncturing the pericarp of maturing pods. It also occasionally damages the herbaceous shoots of young cacao.

The adult (Plate XIII) is a slender insect a little over one centimetre in length, green in colour, with red markings. A large spine tipped with red projects from the dorsal surface of the thorax. The legs are long and spidery.

The eggs are laid in the cushions and peduncles of maturing pods and occasionally in the pods themselves. They are approximately two millimetres in length, elongate, curved and milky white when newly laid. They are embedded in the tissue of the plant, leaving two fine filaments projecting similar to those of *Sahlbergella* spp. (1) but more elongated. One day after oviposition these filaments turn back away from each other and for this reason are distinguishable from those of *Sahlbergella*. (Plate XIII.) The eggs hatch after a period of 14 days. The newly-hatched nymph is green in colour and has no thoracic spine. This is developed in the second instar and remains in the succeeding instars. The second nymphal instar is characterised by the appearance of red markings on the dorsal surface of the abdomen. These become more prominent in later instars. Wing lobes appear in the third instar period. There are five moults before the adult stage is reached. The nymphal life averages 19 to 20 days, the minimum period observed being 17 days and the maximum 22 days, the life from egg to adult averaging 33 to 34 days. One or two days prior to the final moult the wing lobes turn black.

The nymphs do not necessarily prefer shaded situations, and therefore punctures are found on all parts of the pod, and not concentrated as in the case of *Sahlbergella* spp., where feeding is confined to the underside of pods.

Although one adult is capable of making as many as 100 punctures per day, little damage is caused. As stated previously, very rarely other than maturing pods are attached. The punctures do not go to a depth of more than two to three mm. An area of about one mm. in radius around each puncture dies, and a corky scab

PLATE XIII.

Fig. 1.

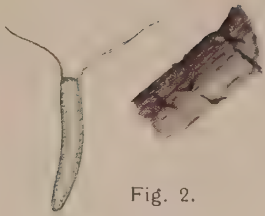

Fig. 2.

Fig. 3

Fig. 4.

Fig. 5.

Cacao Mosquito (Helopeltis bergrothi Reut.)

Fig. 1. Adult.
Fig. 2. Egg enlarged and eggs in situ in pod peduncle.
Fig. 3. Pod damage by adult and Nymphs of Helopeltis.
Fig. 4. Third instar nymph.
Fig. 5. Fifth instar nymph.

is quickly formed, thus lessening the chances of infection by pod disease. Very occasionally young pods may be attacked, causing mal-formation and possible abortion.

Damage to herbaceous shoots is of very rare occurrence. Only one case has been observed by the writer, and that at Asamankese, in 1922, on cacao one to two years old. The area in which this cacao was growing had been cleared of all vegetation before planting. Secondary growth consisted chiefly of a species of *Ipomœa*, an alternative food plant of *Helopeltis*. *Helopeltis* was breeding on this and the adults doing a certain amount of damage to the young cacao. On one occasion an attempt at oviposition in a young cacao tree about four years old was observed. The egg was not fully inserted in the herbaceous shoot and did not hatch.

From experiments carried out on the longevity of *Helopeltis* adults, it was found that adult females could live in captivity for as long as six weeks. One adult was kept alive for 39 days and at the end of this period appeared to be as healthy as ever. Records could not be carried further, as cessation of other work resulted in all records being closed down at Asamankese. During this period 20 ovipositions were observed at practically daily intervals. In all, 126 eggs were laid, the most at one oviposition being 16. It is probable that a very much larger number of eggs are laid by one female as Patterson (2) states that he has kept females alive for as long as 70 days.

A period of seven days elapses between the final ecdysis and first oviposition.

A large number of alternative food plants of *Helopeltis* has been listed. Patterson (3) lists 60 odd species of plants representing 20 natural orders. Most of these are imported plants and ornamental. Probably the most important food plants in the cacao growing areas are *Ipomœa* spp., *Acalypha* spp., and *Capsicum* spp., and a number of species of Malvaceæ and allied orders. *Helopeltis bergrothi* also attacks cotton and can be a serious pest of this plant. The question of soil conditions obviously plays an important part in attack on alternative food plants. Whereas in one area one species of plant will be readily attacked, in another *Helopeltis* cannot be made to feed, but will readily feed and breed on another, and *vice versa*.

Andrews (4), working on Tea *Helopeltis* in India, stated that there appeared to be a relation between the chemical composition of the soil and the amount of *Helopeltis* attack. Whether the same applies here has not been ascertained. In the writer's opinion it is much more probably due to physical soil conditions.

Helopeltis attack on cacao is found throughout the cacao belt, where conditions are favourable for its attack occur. These conditions are poor water retaining power of soil, shallow soil and lack of shade. All these conditions result in undue variations in humidity in the area in which the cacao is growing. It can therefore be said that *Helopeltis* prefers areas where humidity is low or variable throughout the year. *Helopeltis* attack is not commonly found in areas where pod diseases are common, and

therefore the risk of secondary infection by pod disease is low. In areas where cacao is growing under conditions favourable to attack the overhead shade may be sufficiently dense to preserve the ground humidity. However, as soon as a hole is made in the canopy of shade, attack at once commences on the pods of the surrounding trees.

Natural controls of *Helopeltis* are few. Ants prey on the nymphs to a considerable extent. A Hymenopterous parasite of the nymphs has been observed, but has not yet been bred out. The degree of parasitism is unknown, but is not high. Lean (5) working on *Helopeltis bergrothi* attacking cotton in Nigeria, has bred out a Braconid parasite from the nymph, namely, *Euphorus* (?) *nigricarpus*. It is possible that this is the same parasite that occurs in the Gold Coast. Lean also records the larva of a Syrphid fly which attacks the nymphs at the time of ecdysis. No Syrphid predator has been observed attacking *Helopeltis* on cacao.

Cultural controls consist of the replacement of overhead shade and the filling up of holes in the top canopy of foliage with temporary shade such as Plantains or *Gliricidia*. Young unestablished cacao growing in obviously unsuitable areas should be destroyed.

Artificial controls are impracticable and at present unwarranted.

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Cacao Aphis.

Cacao aphis, *Toxoptera aurantia* Boy. (Plate XV, fig. 1), attacks herbaceous foliage only and cannot live on mature leaves. It is commonly found on the under surface of succulent leaves produced by young cacao following other insect attack and on the suckers put out from the trunks of mature cacao trees when these are left unpruned.

Infestation commences from the progeny of one winged individual. A number of asexual generations are produced until the foliage hardens when a winged generation of females is produced and these migrate elsewhere. Reproduction is parthenogenetic, but it is probable that males are occasionally produced. No males have been observed by the writer.

The number of days of nymphal life from birth of nymph to winged or unwinged adult was found to average seven days.

PLATE XIV.

Fig. 1.

Fig. 3.

Fig. 2.

Fig. 6.

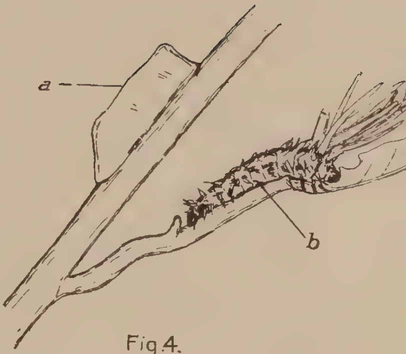


Fig. 4.

Fig. 5

Fig. 7.

Fig. 8

MINOR PESTS OF CACAO.

Fig. 1.—Earias biplaga. Wlk. (Female.)

Fig. 2.—Earias biplaga. (Male.)

Fig. 3.—Egg of Earias biplaga on stipule of leaf-bud.

Fig. 4.—(*a*) Cocoon of Earias biplaga.
(*b*) Full-grown larva of Earias biplaga.

Fig. 5.—Diacrisia rattrayi. Roths.

Fig. 6.—Cocoon of parasite of Earias biplaga.

Fig. 7.—Adult parasite of Earias biplaga.

Fig 8.—Hyperparasite of Earias biplaga.

PLATE XV.

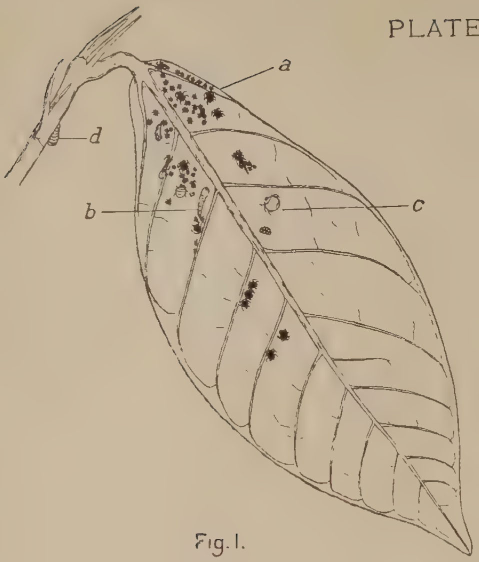


Fig.1.

Fig.2.

Fig.3.

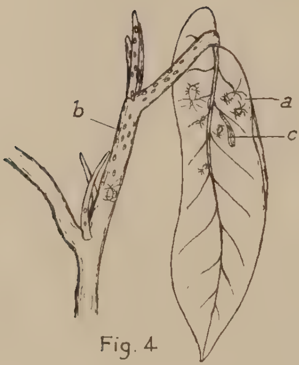


Fig. 4

Fig.5.

Fig.6.

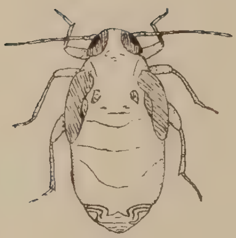


Fig.7.

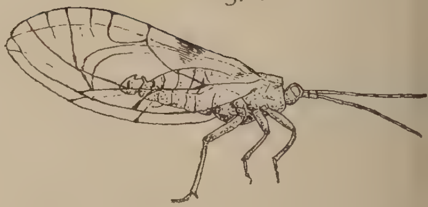


Fig.8.

MINOR PESTS OF CACAO.

Fig. 1.—Cacao Aphis. (Toxoptera aurantia Boy.)
(*a*) Nymphs and unwinged females.
(*b*) Larva of Paragus sp. feeding on Aphis colonies.
(*c*) Larva of Novius sp. feeding on Aphis colonies.
(*d*) Cocoon of Paragus sp.

Fig. 2.—Baccha sinuata. Brun.

Fig. 3.—Novius sp.

Fig. 4.—Cacao Psyllax. (Mesohomotoma tessmanni. Aulm.)
(*a*) Nymphs. (*b*) Egg pits. (*c*) Larva of Baccha sp. feeding on nymphs.

Fig. 5.—Paragus marshalli. Bezzi.

Fig. 6.—Paragus borbonicus. Macq.

Fig. 7.—Nymph of Mesohomotoma tessmanni. Aulm. (Enlarged.)

Fig. 8.—Adult of Mesohomotoma tessmanni. Aulm. (Enlarged.)

The number of nymphal stages was not ascertained. An extra nymphal instar bearing wing lobes is produced prior to the production of a winged adult. Colonies are attended by a species of black ant.

Natural enemies are common. The most important of these are the larvæ of two Syrphid flies which prey on the colonies, namely, *Paragus marshalli*, Bezzi. (Plate XV, fig. 5), and *P. borbonicus* Macq. (Plate XV, fig. 6), and a Coccinnellid beetle, *Novius* sp. (Plate XV, fig. 3), the adults and larvae of which also are predaceous.

Except when attacking suckers put out from trunks of mature trees, attack is secondary to bad cultural conditions or secondary to other insect attack, and depends on flushes of new foliage following unfavourable climatic conditions. In the latter case control consists of removal of the pre-determining cause.

Attack is not sufficiently serious to justify artificial methods of control, even if these were practicable.

Cacao Psylla.

Cacao Psylla, *Mesohomotome* (*Udamostigma*) *tessmanni Aulm.* (Plate XV., figs. 7 and 8), also attacks herbaceous foliage only and cannot survive on mature leaves. Nymphs and adults suck leaf buds and succulent leaves produced by young cacao usually following other insect attack. Severe attack results in shortening of the internodes and consequent bunching of foliage.

The adult measures about half a mm. in length, with two pairs of membranous wings sloped over the abdomen. They are incapable of sustained flight, but hop from leaf to leaf, using the wings as planes. The hind legs are stout and used for jumping.

Eggs are laid in the bracts and unfurled leaves of developing leaf buds. They are laid in pits, each egg being attached by a minute hook. The egg period has not been ascertained, but is probably from five to eight days. The nymphs are pink in colour and flattened. They produce a waxy secretion from the abdomen in the form of threads. This secretion is produced in quantity usually entirely covering the nymph. Attacked foliage is covered with this secretion. Wing-lobes appear in the third instar and succeeding instars. The nymphal period appears to be variable, but an insufficient number of records was taken. The minimum period observed was eight days and the maximum 15 days.

Alternative food-plants have not been ascertained, but nymphs have been observed on a number of undetermined bush plants. *Cola acuminata* is also attacked, and appears to be a more preferable food-plant than cacao.

Natural enemies consist of the larvæ of the Syrphid flies, *Baccha picta Wd. var. Superpicta* Bezzi., *B. præusta* Bezzi and *B. sinuata* Brun. (Plate XV, fig. 2). The larvæ of these Syrphids are common in *Psylla* colonies.

As attack results from the same conditions favourable to *Aphis* attack control measures that apply for *Aphis* apply here.

SCALE INSECTS.

Although scale insects are considered serious pests of cacao in other cacao producing countries, they are of comparatively no importance here at present.

The following scale insects have so far been recorded in this country :—

Stictococcus sjostedtii. Ckll. attacking succulent shoots and pod peduncles. Attended by the Red Tree Ant, *Oecophylla smaragdina.*

Stictococcus multispinosus. Newst. attacking pod peduncles. Attended by black ants.

Ferisia virgatus. Cokll. Mealy bug attacking pod peduncles and attended by black ants.

Aspidiotus ? cyanophylla. Sign on cacao foliage. A number of other species have been observed on stems, leaves and pod peduncles, but have not yet been determined.

LEAF EATING INSECTS.

Earias biplaga. Wlk. (Plate XIV, figs. 1 and 2).

Earias biplaga is a small Tinæid moth measuring approximately a little over 1 mm. in length and 2 mm. from wing-tip to wing-tip. When at rest the wings are carried folded over the body. The adult is nocturnal.

The female is green in colour with a large brown blotch on each fore wing. In the male this mark is absent.

Eggs are laid singly at night on the bracts of leaf buds. The larvæ commence to feed inside the leaf bud and eventually complete their life on the succulent foliage and also the bark. The full grown larva is green-brown in colour and spiney. Pupation takes place on the stems in a tough fibrous boat-shaped cocoon. The larval stage varies from 18 to 21 days, and the pupal period eight to nine days.

Attack is confined to new flushes of foliage, and is common on young cacao which is improperly shaded and growing under bad soil conditions. Attack may result in complete defoliation of the newer foliage of young trees. It commonly follows *Sahlbergella* damage attacking the new foliage put out from the lower part of the stem after the upper foliage has been destroyed.

Natural controls consist of two undetermined Hymenopterous parasites, one of which, a Braconid, illustrated in Plate XIV, fig. 7, which is highly hyper-parasitised. No other controls have been observed.

Alternative food plants are few in the cacao belt. *E. biplaga* is the most serious boll worm of cotton in British Togoland. In open country it has been bred from Okro, other *Hibiscus* spp., and *Urena lobata.*

As attack on cacao is always associated with lack of shade and poor soil, conditions control obviously can only be brought by remedying these conditions.

When secondary to *Sahlbergella* attack control consist of first controlling the primary cause.

Stomach poisons such as lead or calcium arsenate can be used with success where practicable.

OTHER LEAF EATING PESTS.

A weevil at present undetermined and of unknown genus, attacks the back of herbaceous shoots of young cacao under similar conditions that are favourable to *Earias biplaga* attack. Occasionally damage is serious.

The Rutellid beetle, *Adoretus hirtellus*, has been reported as eating foliage of older trees at Aburi some years ago. Attack has not been observed recently.

The Curculionid beetle, *Apoderes flavoebenus*, does no economic damage to cacao. It is only mentioned here from a point of interest. The adult selects a young cacao leaf and makes a series of transverse cuts in the mid-rib from the apex of the leaf to about half-way towards the base, thus destroying its rigidity. The leaf is then rolled up, the beetle using its legs and jaws. Just after commencing to roll, an egg is laid on the tip of the leaf, so that it will be enclosed in the roll. The ends of the cylinder are folded in so that an enclosed cylinder is formed and the leaf rolled up to about half its length. Owing to the cutting of the mid-rib the leaf remains rolled up after the beetle has left. The egg hatches and the legless larva feeds on the walls of the cylinder, eventually pupating inside. The adult emerges by biting its way out.

Other leaf-eating insects are the larvæ of the Arctiid moths, *Diacrisia mundata* and *D. rattrayi* (Plate XIV, fig. 5), which are omniverous and occasionally attack moribund young cacao. There is also an undetermined cacao leaf roller which is of minor importance economically.

Other leaf-eating caterpillars have been observed, which, on occasion, have done serious damage. These attacks have, however, been purely sporadic in occurrence, the only danger being that at some time they may become important pests.

INSECTS ATTACKING PODS.

Moth Borer of Cacao Pods. Characoma stictograpta. Harp.

Little is known of the life-history of this Noctuid moth. Eggs are laid on the surface of the pod at the point of contact of two pods or a pod with the main trunk, the young larva hatching out and boring into the pericarp of the pod, piling up heaps of grass and silk outside the tunnels. Only the pericarp is attacked, and the seeds develop normally unless fungus disease follows. Attack is more prevalent in areas of heavy shade and humidity, *i.e.*, those areas where fungus diseases predominate. Undoubtedly damage by the larvæ of this moth results, in a number of cases, in subsequent fungus infection.

Pupation takes place on the surface of the pod or in the ground. One Hymenopterous parasite of the larva has been found, but has not yet been determined.

A black ant, probably *Crematogaster* sp., has been observed to eat the epidermis of nearly mature pods at Aburi. The epidermis is carried away to the arboreal nests of the ants and probably utilised in the fungus gardens.

INSECTS ATTACKING STEMS.

Tragocephala gorilla, Thomp., bores in branches of mature cacao up to three inches in diameter, but is uncommon as a serious pest.

Tragocephala chloris, chev. (Plate XVI, fig. 4) and *T. gorilla* bore in young cacao usually growing under unsuitable conditions. The stem is girdled just below the main growing shoot and an egg inserted just below. This prevents further growth and possible distortion of the egg. The young larva bores down the stem, making frequent holes to the exterior to get rid of its frass. The larval life lasts from four to five months. When ready to pupate the larva turns round in its bore and plugs the upper end with frass.

The Cerambycid beetles, *Glenea* spp. (Plate XVI, fig. 3) bore in the base of old cacao trees just under the bark and occasionally cause complete girdling of the tree. Attacks by these beetles are localised and are uncommon.

The larva of the Cerambycid, *Mallodon downesii*, Hope (Plate XVI, fig. 2), bores in the main stems of older cacao, particularly in cacao growing in areas that have been deforested since cacao were established. The tunnels are extremely large and have no connection with the outside. Trees are completely or partially destroyed. Owing to there being, as a rule, no frass holes to the outside, the beetles cannot be located, and excision causes more damage than the ravages of the larvæ. *Mallodon downesii* has also been recorded as attacking rubber in heavily deforested districts. Normally, *Mallodon* is a forest tree borer, and it is possible that in areas in which recent heavy deforestation has occurred the beetle has adapted itself to cacao and rubber in the absence of its usual food.

The moth borer, *Eulophonotus myrmeleon*, Feld. (Plate XVI, fig 7), has been recorded as attacking cacao, but is uncommon. The larvæ bore in the stems of mature trees and when ready to pupate eat out a perpendicular slit in the bark. Pupation takes place inside the slit, the full-grown moth emerging through the opening.

Occasionally shot-hole borers also attack the main stems of cacao. *Xyleborus nitidipennis*. Murray, and *X. urichi*. Samps. have been recorded as attacking cacao in this way.

The larvæ of the Cerambycid beetle, *Armatosternum buquestiana* Wh., has also been recorded as boring in cacao.

INSECTS ATTACKING ROOTS.

An undetermined species of Termite has been observed to attack the roots of young cacao in Togoland and the Trans-Volta District of the Colony. The root system is entirely destroyed. This is the first record of Termites attacking healthy cacao. Control consists of destruction of nest and queens in the vicinity.

PLATE XVI.

Fig. 1

Fig. 2

Fig. 3.

Fig. 4

Fig. 5

Fig. 7.

Fig. 6.

MINOR PESTS OF CACAO.

Fig. 1.—Cacao Pod Borer. (Characoma stictograpta. Harp.)

Fig. 2.—Mallodon downesii. Hope.

Fig. 3.—Glenea fasciata. F.

Fig. 4.—Tragocephala. Chloris. Chev.

Fig. 5.—(*a*) Egg of Tragocephala sp. in situ.
(*b*) Girdled stem above egg.

Fig. 6.—Stem cut away to show pupa of Tragocephala sp.

Fig. 7.—Eulophonotus myrmeleon. Feld. (Female)

PAPER No. XVIII.

ATUABO COCONUT PLANTATION.

By C. H. KNOWLES.

The Atuabo coconut plantation is one of the plantations, established in the Western, Central and Eastern Provinces, to demonstrate to the people the use and value of the coconut palm for commercial purposes and especially on land near the coast which is generally regarded as of little use for permanent crops.

The plantations are established on communal land, leased for the purpose at a nominal rent. When Government has recouped the expenditure involved, the plantations will be handed back to the people.

The idea of using public money for the benefit of owners of land is perhaps an unusual one, but the establishment of new industries is considered of such great importance that, so long as there is a reasonable prospect of the amount expended being regained, the use of public funds in this manner is justified.

The Site.

The town of Atuabo (population 738 in 1921) lies about halfway between the ports of Axim and Half Assinie—the latter being at the extreme west of the coast line of the Colony. The Atuabo plantation holds a central position in a considerable belt of similar land and may be taken as quite typical of the belt. The plantation are on the town boundaries of Atuabo and extends to the village of Anochi. It forms a narrow, and approximately rectangular, block some seven times as long (along the coast) as it is wide (inland). Since operations were intended on a plantation scale, the area aimed at was 340 acres. This, however, could not be realised, but by small additions to the original block a total of 295 acres has been obtained.

Commencement.

Work commenced in the middle of 1920 with clearing lines 30 feet apart, some 6 feet wide, and selecting and clearing a site for a nursery of seednuts. The land was covered with a fairly heavy growth of Phœnix and Borassus palms between which were growing small trees and scrub. The vegetation formed a fairly dense covering, particularly on the inland boundary, which borders on swampy land which in the wet season practically forms part of the lagoons which run parallel to the coast.

Seednuts.

Seednuts were obtained from Lome (Togoland—now French territory, but in 1920 under occupation by a combined Anglo-French force). Several excellent plantations exist in Togoland, coconut planting having been encouraged by the Germans.

Owing to transport difficulties, many losses occurred in the seednuts, mostly through germination before the nuts arrived. Between August and December, 1920, some 20,000 seednuts were received at the plantation and set out in nurseries. Various additions were made to the nurseries from time to time until approximately 30,000 had passed through the nurseries. A fire in March, 1921, destroyed 3,000 seedlings in the nurseries, while cattle, grasshoppers, and Rhinoceros beetles are reported as having done damage to the seedlings in addition to a number scorched by the sun as well as those lost in transit referred to above.

Clearing the Lines.

The original clearing was arranged to deal with 6 feet strips. 30 feet apart, with crosslines 25 feet apart, in the centre of the intersections of which the nuts would be planted.

Lining-off was not as easy in a heavy growth of bush as it would have been on a cleared land, hence an undue expenditure on this work, both for the original lining and in subsequently correcting errors.

Transplanting.

Preparations were made for transplanting to commence in the wet season in 1921, and by September of that year some 240 acres had been cleared (in lines) and 156 acres were planted, with some 9,088 plants. The method of planting adopted was the usual one of setting the seedlings at the bottom of deep open holes and allowing the soil to wash in gradually.

Clean Weeding.

The lines originally cleared had become overgrown the latter part of 1921, and necessitated much additional attention. It was seen that the land would have to be completely cleared, and clean weeding practised. The bush in between the rows of coconuts was therefore attacked, and by the end of the year it had practically been completed. It is certain that both the original clearing in lines and the subsequent clearing of the bush in between was more costly than would have been the original clearing of the whole area. As soon as the condition of the land permitted, the people were encouraged to plant groundnuts, shallots, cassava, gourds and certain other crops in between the coconuts. As the palms spread, this inter-cropping was curtailed, and it disappeared in 1926 in the bearing areas. It is not considered that the palms were harmed in any way by this catch-cropping—on the other hand it is suggested that the cultivation of the land has been beneficial.

In April, 1924, a count of the palms showed that 12,675 were established (218·5 acres); 1,315 failed (22·7 acres ; 49 blanks (0·9 acre). The last-named were places which had evidently been overlooked in transplanting. The vacancies in due course were all supplied, and in 1923 the area planted reached a total of 295 acres, the present area.

Climatic Conditions.

The area in which the plantation is situated is the wettest in the Gold Coast, the annual rainfall being about 60-70 inches on an average of 110-120 wet days a year. The coconut palm is very accommodating in the matter of rainfall and can adapt itself to a variety of widely differing climatic conditions. The copra industry is established in some parts of the Philippine group with 240 inches of rain a year, and in Keta (Gold Coast) and some South Pacific Islands the palms bear satisfactorily under about 20 inches a year.

The advantage of the heavier and more regular rainfall is very pronounced in the early stages of the history of a coconut plantation. There is less trouble in establishing and maintaining a nursery, while after transplanting, losses are reduced to very few instead of the formidable percentage lost in dry places. It is easier to maintain uniformity in the development of the coconuts in wet places—thus reducing the cost of establishing and tending to hasten the returns.

The Young Palms.

The young palms developed in a normal manner. Forty were recorded as flowering at the end of 1924, since which date flowering and fruiting have increased regularly and rapidly.

Pests, etc.

A complete list of known pests of coconuts in the Gold Coast has not yet been compiled, but attention is being given to the matter. There is no evidence of any pest so serious as to endanger the success of coconut planting. Rhinoceros beetles and grasshoppers did some damage in the nurseries and in early stages of the plantation. A number of seedlings were scorched by the sun when in the nurseries, while cattle were exceedingly troublesome at one time. Scale has regularly been present and some leaf-eating caterpillars, but both the scale insects and the leaf-eaters are kept in check by natural enemies.

Use of Early Maturing Plants.

Fruiting was fairly common among the older palms in 1926, and seed was selected from the fruit so obtained for planting purposes.

Some objection has been raised to the use of such early seed for planting purposes, hence it seems desirable to offer some remarks on the question.

The average age for coconut palms to begin to bear is seven to eight years. Instances are known of palms under plantation conditions bearing when only four years old, while other palms at 20 years have never had fruit. The difference in financial results of two plantations, one of which had most of its palms bearing at four years, while the other at 20 years had not commenced to give revenue, needs no emphasizing. It is not likely, of course, that the majority of palms on a plantation would be either extremely early or extremely late bearers, but since the establishment of a coconut plantation is a costly undertaking, every effort should naturally be directed towards taking whatever steps are possible to hasten the arrival of the first crop.

Early or late fruiting appears to be a quality capable of being transmitted through the progeny of a plant. It therefore would seem to be a quality which can be improved by careful selection of early bearers. With permanent crops, the plants to give the earliest crops are very important, provided they are sound and robust plants of a satisfactory type, and provided further the crop is satisfactory as regards both quality and quantity. There is no evidence that early-bearing coconut palms cease to bear at an early age, or are otherwise unsatisfactory for plantation purposes. A sound mature seed of proper development and having the desired characteristics, but produced by a very young parent plant, shows no physiological differences whatever to one from a much older plant.

The general advantages in using the first crops for seed are the resulting saving in time and the absolute certainty of selecting from early bearing plants.

The Crop.

The plants at Atuabo were bearing good crops in October, 1927. The bunches were large, and the nuts of fair size. Young coconut palms frequently lose what seems to be a large number of nuts which fall off the branches at an early stage. This was in evidence at Atuabo. It is of no particular importance, as the young bunches are made up of many more nuts than the palm could mature. As planting commenced at the end of the plantation near Atuabo, and gradually proceeded towards the Eastern boundary, fruiting is principally in the Western block. It will not be possible to offer figures pretending to show the yield per acre until bearing is more general. The nuts are allowed to fall from the palms. This ensures that the nuts are ripe, and the husks are in good condition for fuel.

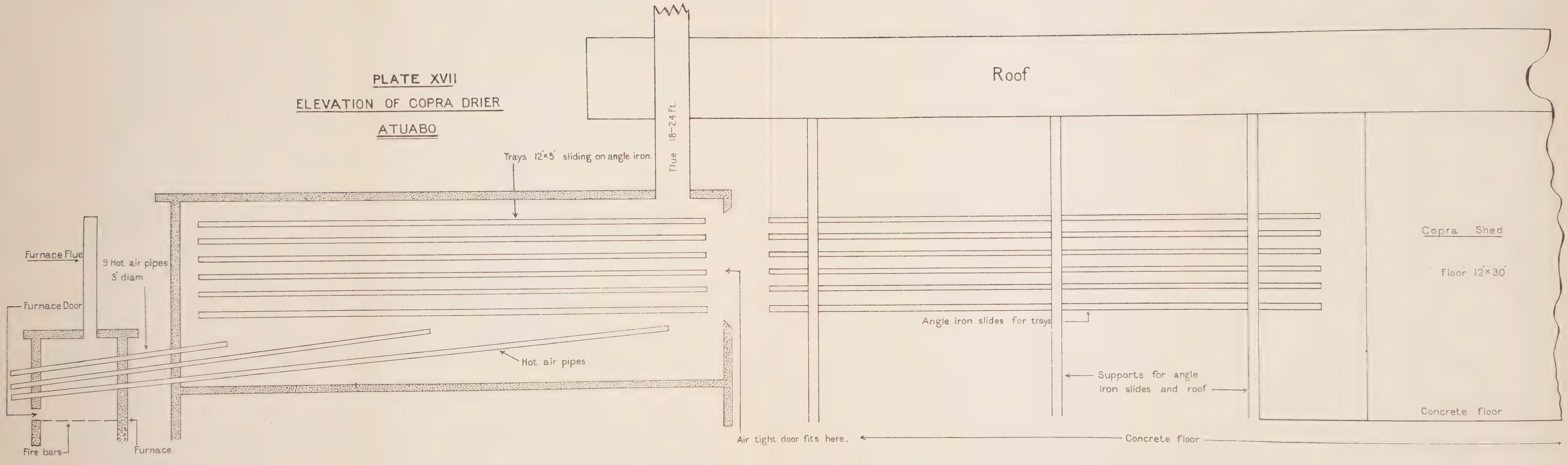
Treatment of the Crop.

Sun drying is carried on in many places where the rainfall is heavier than at Atuabo. But since the plantation is serving as a demonstration plantation, it was decided to instal some form of artificial dryer as the main means of working up the crop, depending on sun-drying to supplement artificial drying when possible and

PLATE XVII

ELEVATION OF COPRA DRIER

ATUABO



desirable. There are several forms of proprietary artificial drying-machines on the market for various crops and including some for copra. A collection of such machines would doubtless be instructive to enable the proper comparisons to be made, but such a procedure is, of course, out of the question on a small plantation.

Since, however, the principles of drying by hot air are well known, the building of a drying apparatus presents no particular difficulty, and if constructed of material obtainable locally, has the additional advantage of cheapness and certainty of construction within a specified time. Dryers built of wood and concrete with a few iron parts, generally obtainable in a country of this kind, were designed by the writer several years ago and have been constructed and usefully operated. The small dryer at Atuabo is of this design. A diagram is attached. (Plate XVII.)

Briefly, it is a chamber of concrete, having a series of perforated trays which can be run in and out of the chamber on slides of angle iron. An air-tight door is provided. A series of iron pipes passing through a furnace enables a supply of hot air to be delivered into the chamber at the bottom, while at the top at one end a wooden flue of suitable area and length creates a " draught " and provides for the circulation of hot air over the kernel of the coconuts spread on the trays. The hot air removes the moisture and converts the kernel into copra.

The dryer at Atuabo has a chamber 12 feet by 5 feet by 4 feet, accommodating five trays, which hold a charge of about 1,200 to 1,500 lbs. of kernel, giving about 700-900 lbs. of copra. By working continuously the kernel can be completely dried in 24 hours, but, unless there is a pressing need, it is better to leave the charge in for 48 hours, banking the fire at night.

The husk from the coconuts, the kernel of which forms a charge, are sufficient to heat the air for drying that charge. The tendency is to get too great a fire, which would heat the air to such an extent as to char the kernel.

The dryer was built at a cost of under £200, including the comparatively heavy freight along the beach from Axim. Considerable trouble was experienced in regard to the supplies of iron pipe and angle iron—materials in common use in most countries and which undoubtedly would be stocked here when demand arises. There are certain points which must be carefully attended to—the first is that the building, door and flue must be *air-tight*. The best form of flue is a square one made of the proper length of boards 12 ins. wide, giving a cross section of 11 ins. square, with no joints except at the corners. The boards should be smooth to provide a good fit, and tar, thick paint, putty or other material should be painted on to the wood before forming the joints. Sound boards are essential. A large dryer should have two, three or more flues, all 11 ins. square and built in an air-tight manner—rather than one of larger cross section, which is never likely to be air-tight.

The iron tubes which provide the hot air supply pass through a furnace separated from the drying chamber to avoid risk of fire, they communicate with the outside air at one end and the chamber at the other. The tubes should be in series of three, six, nine, or other number divisible by three, and they should project into the drying chamber so that one-third of them communicate hot air near one end, one-third about the middle and the other third take the hot air to the far end. The hot air is thus more evenly distributed. If inspection shows that the drying is proceeding unevenly, correction can be made by blocking the outer end of the proper air tubes. Baffle plates of perforated iron or other metal can be put over the inner ends of the air tubes to aid further the more even distribution of the hot air. Thermometers are a necessity for the proper regulation of temperature. The distance-reading thermometers enable the indicating dials to be brought to a convenient spot, one recording the temperature of air on entering the chamber and another the temperature of air at the foot of the flue. As drying proceeds, the difference between these will decrease. Air should enter the chamber about F. 160° (82° C.). When the kernel is quite fresh a few degrees higher would do little harm, but it is better to avoid all risk of over-heating by maintaining a regular temperature as suggested. A sketch plan of the dryer is shown in Plate XVIII.

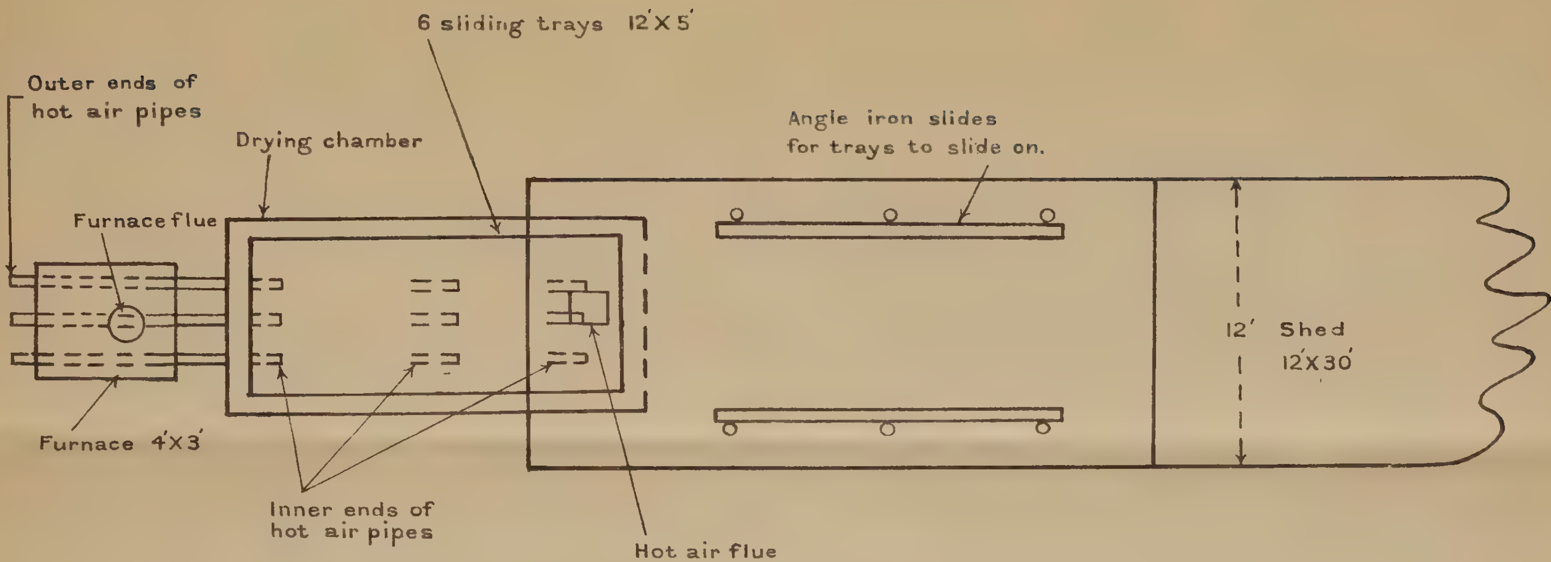
The following list shows the crop dealt with since the dryer was erected:—

	No. of Nuts dealt with.	Wt. of Green Copra.	Copra.	No. of Nuts per Ton of Copra.
		Lbs.	Lbs.	
October	2,442	—	708	7,726
October	17,752	10,000	6,057	6,565
November ..	25,000	15,587	8,876	6,308
December ..	23,419	12,616	8,303	6,317
Total ..	68,613	—	23,944	6,377 average.

The large number of nuts per ton seems to indicate that they are very small, a fair average being well below 6,000. As a matter of fact, the nuts had been collected some months before the dryer was ready for use or before other satisfactory arrangements could be made for working them up into copra. They were placed in heaps and many of them germinated. When splitting for drying, those in which germination had not proceeded very far were used, but since some of the kernel had been used up in the processes of germination, the yield of copra was reduced, hence the number of nuts required to make a ton was increased.

The percentage of copra to kernel, 58·4, is satisfactory, so far as can be seen without analyses of the kernel and copra, which are not yet complete.

PLAN OF COPRA DRIER, ATUABO.



Reproduced at Survey H.Q. Accra, 1928.

The following is the complete list of the crop, showing the use made of the nuts:—

Nuts Collected.		Disposal.	
To March, 1926 ..	81	For Copra.. ..	45,194
April, 1926—March, 1927	29,737	For Seed	2,076
April, 1927—Oct., 1927 ..	109,078	Exhibits	187
		Distributed ..	7,858
		Useless	3,369
		On hand	80,212
	138,896		138,896

The Cost of the Plantation.

Expenditure on establishing a plantation can conveniently be regarded as ended when crop begins to arrive in appreciable quantities. From the list above it will be seen that considerable quantities of nuts were gathered from April, 1927-28, so it is proposed to take expenditure up to the end of March, 1927, as for the establishment, and from April, 1927, as working expenses.

In order to encourage the planting of coconuts, the Government did not confine its interest to the establishment of the plantation. The overseer employed for the first six years was a specially qualified officer from Ceylon, who, in addition to the supervision of the plantation, carried out itinerant duties in the neighbourhood. It would therefore be unfair to charge against the establishment of the plantation the whole of this officer's salary.

The cost of establishing the plantation is, allowing for the above, as below:—

Per acre for 295 acres.

	£	s.	d.
Seed	1	4	1
Tools		2	5
Labour (*)	11	11	10
Rent		4	10
Supervision	6	0	0
	£19	3	2

(*) Labour item includes erection of temporary quarters for overseer and labourers, nothing being shown under buildings. The cost of seed is high for the reasons given previously. It has been indicated earlier where savings should have been possible in the labour bill.

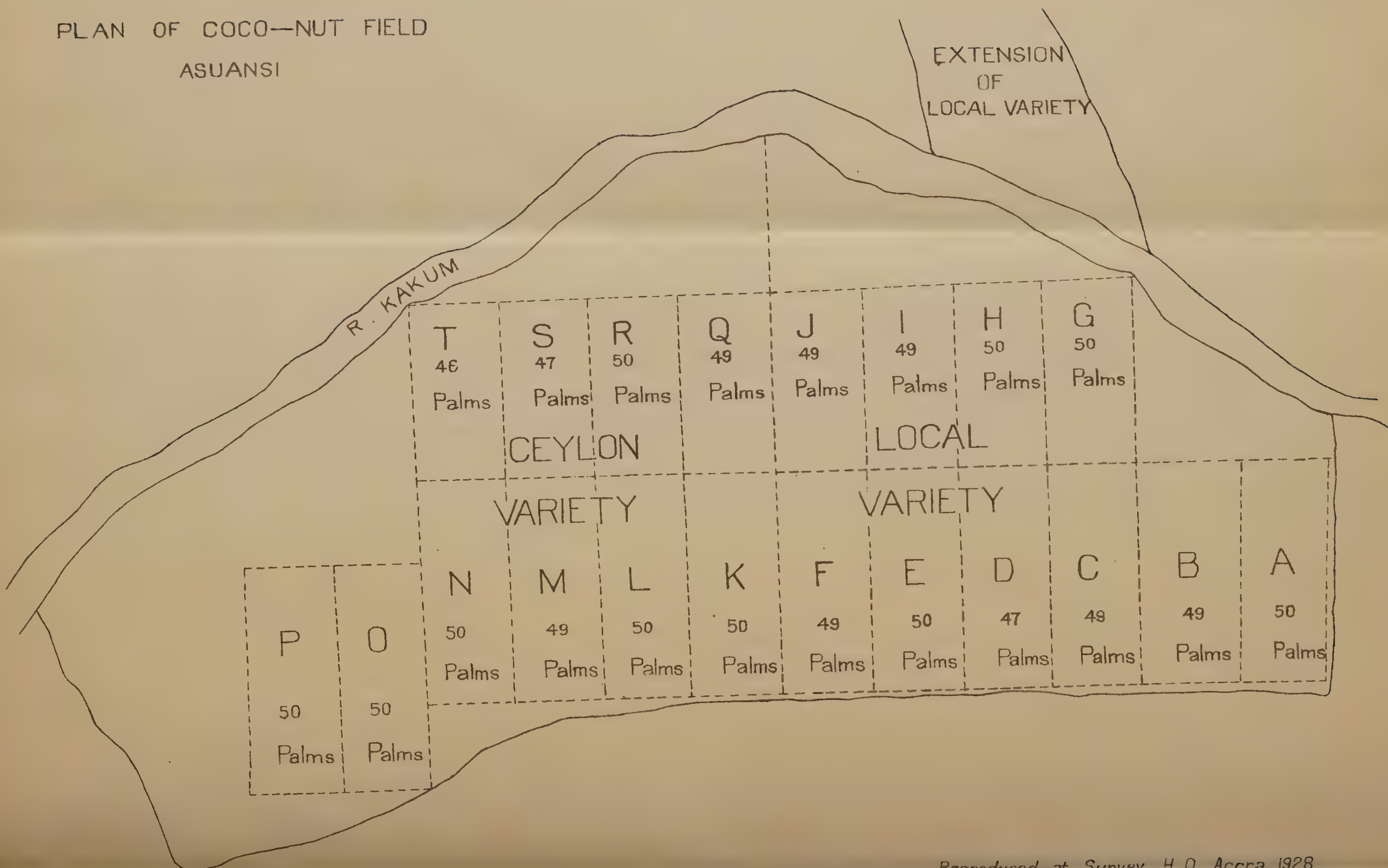
Faults in Copra.

The chief faults of copra in this country are immaturity of the nuts, and mould on the finished product. The first fault is

due entirely to the method of picking the bunches from the palm. The method recommended is to allow the nuts to fall naturally, which they will do when they are mature and the husk is nearly dry. The kernel is then as fully developed as it will be, and in the best condition for turning into copra, and the husk is suitable for use as fuel.

The presence of mould is an indication of insufficient drying. All products which are made into a marketable condition by removing surplus water are liable to be attacked by moulds of various kinds unless the drying is carried far enough. A little experience is sufficient to enable one to judge by the appearance of the material when split across so as to expose a fresh internal surface, whether the drying has been carried far enough, which is the case when the freshly exposed surfaces of the kernel, on being split across, show a uniform pearly appearance with no white bands, which, during the earlier stages of drying, show as belts parallel to the inner surface of the kernel and of gradually decreasing width.

PLATE XIX



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PAPER No. XIX.

VARIATIONS IN YIELDS OF COCONUTS AT ASUANSI.

(*The field work dealt with in this paper has been conducted by* A. B. CULHAM *and* J. STEELE, *and the data collected by* S. R. B. FLETCHER. *The paper has been prepared by* N. P. CHAMNEY.—*Editor.*)

History of the Trial.

The local variety of coconuts used in one section of this trial was planted in 1910 and the Ceylon variety in 1912. In each case the planting distance was 25 feet by 25 feet.

In the case of the local variety, 30 planting lines were made with varying numbers of trees according to the configuration of the ground, and also the fact that a river bounded the back of the area. A total area of 10·5 acres was covered and 713 palms planted. Of these, 673 have survived and 100 of these are not fruiting.

The area covered by the Ceylon variety is 12·3 acres, with 41 planting lines, of varying content for the same reasons as in the case of the local variety.

The area varies considerably, being dry on rising ground, with rock outcrops on plots C, D, E, F of the local variety hereinafter mentioned, and falling to swampy low lying ground in plots O and P of the Ceylon variety. This probably accounts for the large average deviations on the plots employed, which were, however, the most convenient divisions which could be employed.

Plate XIX shows the arrangement of the field and the method of dividing it to get the ten most equal plots for each variety.

In each variety the plots were arranged so as to get as near 50 trees as possible in each plot, and at the same time to avoid the outlying areas where, owing to environment, vacancies and non-fruiting trees were frequent. It is obviously impossible to reproduce the actual spot plans made marking the position of each tree as the result would be too unwieldy, but the plans and notes thereon show that the empirical plots employed are in the best areas available.

From 1919 the individual records of the trees were kept, and this has been continued to date. The tabulated records involve 12,288 separate observations, and have had to be analysed in order to bring them within the space available for reproduction.

Actual possibilities of selection of high yielding strains and other methods of improving yields which were the original purpose of the trial are outside the scope of this paper, and are therefore left to a future date for consideration.

The Field as a Whole.

The annual yields of the two varieties from the field and per acre are given in Table I. It will be seen the average yield per acre over the whole period 1918-26 is very little different for each variety, and the slightly higher figure for the local variety can be explained by the fact that these palms were planted two years before the others and are nearer, therefore, to full bearing.

The figures compare not unfavourably with those obtained in the East, where the yield varies from 5—40 nuts per productive tree on the average for coastal plantations where the coconut is in its natural habitat. The yield at Asuansi approaches the lower end of this scale in that the average yield is 13—14 nuts, but this figure includes both productive and non-productive trees, and also Asuansi is an inland station some 13 miles from the coast, and must therefore be considered to present artificial conditions.

Rainfall figures to fix the limits within which coconuts can be successfully grown are not available, but the rainfall average for Asuansi, 50·96 in. (Bulletin No. 2 of the Department), appears to be sufficient to maintain good growth and cropping power, even on the parts of the field where the soil is rocky and poor.

The average number of wet days to the end of 1926 is 122, showing an average distribution of rain over the year, a more important point for coconuts than the total deposition.

Coconuts will grow on the coastal belt with much less rainfall, and it may be assumed, therefore, that there is no adverse influence on the yields at Asuansi in this respect.

TABLE I.

YIELDS OF THE WHOLE FIELD.

	Local Variety.		Ceylon Variety.	
Year.	Total Nuts.	Nuts per Acre.	Total Nuts.	Nuts per Acre.
1919	4,657	443	9,257	753
1920	4,127	323	12,789	1,040
1921	6,013	573	13,288	1,080
1922	7,444	709	11,223	912
1923	10,260	977	11,654	948
1924	10,962	1,044	4,640	377
1925	15,060	1,434	5,448	443
1926	19,525	1,859	21,416	1,741
Mean ..	—	920	—	912

The distribution of yield over the year is given as percentage in Table II. No striking cropping season is evident, but the local variety yields on the average heavier crops during March, April and May, while the Ceylon variety bears more heavily during the period August-November.

The differences are, however, very slight, and are not comparable to the definite cropping seasons associated with other crops.

TABLE II.

MONTHLY DISTRIBUTION PER CENT. CEYLON VARIETY.

Month.	1919	1920	1921	1922	1923	1924	1925	1926	Mean.
									%
January	·9	—	6·6	11·2	8·3	11·2	4·3	3·6	5·8
February ..	·4	6·8	5·9	10·9	8·8	21·0	6·9	2·7	7·9
March	11·8	5·8	17·5	7·5	11·7	10·2	6·9	4·1	9·4
April	13·0	—	6·0	8·9	10·8	4·2	5·9	5·8	6·8
May	8·9	6·5	10·7	4·2	11·2	6·4	5·2	8·2	7·7
June	7·4	8·9	3·5	6·4	6·4	9·0	4·6	4·7	6·4
July	10·8	17·9	4·1	8·9	7·8	7·3	7·7	4·4	8·6
August	13·2	12·1	4·3	9·1	6·2	9·2	9·7	8·2	9·0
September ..	9·9	13·1	9·0	8·0	8·6	4·2	11·8	15·6	10·0
October ..	10·3	10·7	13·3	7·7	6·9	4·9	12·6	14·0	10·0
November ..	9·3	12·0	11·3	7·6	6·9	5·8	10·2	12·7	9·5
December ..	4·1	6·2	7·8	9·6	6·4	6·6	14·2	16·0	8·9

LOCAL VARIETY.

Month.	1919	1920	1921	1922	1923	1924	1925	1926	Mean.
									%
January ..	1·7	—	4·9	6·5	4·9	8·1	3·3	5·6	4·4
February ..	·7	5·9	7·4	6·1	6·3	7·8	5·6	5·4	5·5
March	29·6	8·6	14·5	7·0	8·6	9·7	7·1	7·4	11·6
April	16·2	—	15·7	12·9	10·9	9·7	8·6	8·2	10·3
May	10·3	17·9	10·0	6·7	10·8	14·1	8·0	12·3	11·3
June	7·9	12·3	5·1	10·6	8·6	13·5	7·7	5·9	8·9
July	7·9	12·9	7·2	9·1	10·0	9·0	10·7	9·1	9·5
August	7·9	9·9	6·8	11·1	7·3	7·1	10·5	7·7	8·5
September ..	3·1	6·8	7·7	6·9	8·0	5·8	10·9	12·4	7·7
October.. ..	6·3	8·9	4·8	7·6	8·6	4·8	9·6	10·7	7·8
November ..	3·9	10·7	6·9	7·6	7·9	5·1	8·5	8·2	7·3
December ..	4·5	6·1	9·0	7·9	8·1	5·3	9·5	7·1	7·2

Degree of Uniformity of the Field.

In order to test the field for uniformity with the idea of using it for further experimental work, ten plots have been taken out of the area allotted to each variety. These plots are equal in size and exactly similar in shape, and contain five rows of 10 trees each, each plot being therefore twice as long as it is broad.

They run from east to west in each case and are as similarly placed in each variety as it is possible to get them, owing to the difference in shape of the areas treated. A diagrammatic plan of these plots appears in Plate XVIII, with notes on the number of vacancies and non-fruiting palms in each. They are designated by letters beginning with the native variety.

Table III gives an analysis of the 20 plots in order that they may be compared with each other, and also their seasonal variation determined.

Looking first at the seasonal variation, it will be seen that this is very large in both varieties, but more so in the local than in the Ceylon variety.

This is probably due to the fact that the trees are yet comparatively young, and therefore the variation is much larger than will probably be the case when the trees are in full bearing. The deviation is steadily growing less and may be expected to level up considerably during the next few years.

It is, however, too great at present to allow of entirely reliable experimental work being carried on as yet.

The variation between plots is even more marked, and in order to understand this, it is necessary to state that there are distinct areas of swampy ground and rocky thin soil in each area.

TABLE III.

ANALYSIS OF THE 20 PLOTS.

Yields of Nuts per Plot.

Plot Nos.	1919	1920	1921	1922	1923	1924	1925	1926	Mean of 8 years.	Aver. Deviation as % Mean.
				LOCAL VARIETY.						
A ..	839	707	954	1,472	1,819	2,002	2,501	2,512	1,601	37·9
B ..	1,260	803	1,352	1,784	1,692	1,649	2,226	2,595	1,670	25·2
C ..	695	642	731	824	1,280	1,266	2,172	2,039	1,206	42·1
D ..	108	193	226	207	531	483	833	1,050	453	59·7
E ..	55	121	229	115	414	331	773	1,256	412	73·3
F ..	28	91	172	189	372	382	547	1,155	367	66·9
G	631	453	703	797	1,041	1,174	1,657	2,095	1,069	40·0
H ..	79	174	346	143	418	502	863	1,306	479	64·8
I ..	14	96	157	128	454	437	731	1,066	385	74·8
J ..	20	11	109	117	369	288	423	1,049	298	79·3
Mean ..	373	329	498	578	839	851	1,273	1,612	—	—
Average Deviation % Mean ..	98·3	78·3	70·2	81·4	59·4	63·1	54·4	34·0	—	—

CEYLON VARIETY.

Plot Nos.	1919	1920	1921	1922	1923	1924	1925	1926	Mean of 8 years.	Aver. Deviation as % Mean.
K ..	705	1,114	944	724	942	366	301	1,544	885	35·8
L	1,553	1,411	1,315	1,130	1,153	414	346	1,492	1,101	32·8
M ..	1,582	1,560	1,489	1,115	1,294	403	505	1,982	1,241	34·2
N ..	720	1,330	1,263	926	1,027	243	331	1,774	953	41·9
O ..	994	988	1,008	832	700	228	406	1,939	889	38·5
P ..	437	718	993	1,013	804	204	307	1,691	758	46·5
Q ..	41	135	434	262	429	394	195	1,109	499	53·4
R ..	273	552	537	366	448	178	195	836	423	40·2
S ..	617	915	900	534	508	129	191	1,092	498	56·5
T ..	428	937	975	706	776	194	226	1,167	676	43·7
Mean ..	735	966	986	759	808	275	300	1,463	—	—
Average Deviation % Mean ..	52·3	32·2	22·1	34·4	33·2	36·4	26·3	21·8	—	—

These areas fall, roughly, as under:—

Rocky ground, Plots D, E, F, P.

Swampy ground, Plots A, A, M, N, O, R.

On referring to Table III it will be seen that the former have a much higher average deviation than the latter, probably due to the fact that they suffer from lack of soil moisture in dry years, which is an important factor in the growth of coconuts.

In order to conduct satisfactory experimental work on this area, it will be necessary to continue the recording for a year or two more, so as to be able to dispense with the yields of the earlier years while the palms were becoming thoroughly established. After 1921 much greater uniformity can be seen, and another two seasons' yield, 1927-28, will probably bring the variations within reasonable limits.

Comparison of the Two Varieties.

It is difficult to make accurate comparison between the Ceylon and local varieties in that the former was not established till two years after the latter.

A glance at Table I will show that the mean yield over the eight years recorded only differs by eight nuts per acre, and therefore in cropping powers we may expect that there will be little difference between the two. Such points as the weight of nuts and the amount of copra to be derived from an equal weight of nuts of each variety are outside the matter of this paper.

A point that calls for comment is shown in Table III. The greater variation displayed by the local variety, as compared to

the Ceylon may be judged, in the light of the small difference in yield per acre (see Table I), to be due to differences in soil and environment rather than to any inherent difference in the cropping power of the varieties.

On inspection of the palms *in situ*, it is difficult to see as much difference between the varieties or between the plots, and this emphasizes the necessity for careful recording of yields over a period of years and elimination, as far as possible, of likely errors by use of the figures, before experimental plots can be laid out to test really thoroughly any problem which requires elucidation.

PAPER No. XX.

THE DISTRIBUTION OF WHITE AND PINK SEEDS IN THE COLA PLANT.

BY N. P. CHAMNEY.

The Cola tree (*C. acuminata*) bears nuts, which as they contain 2 per cent, of caffeine and 2 per cent. of theobromine, are of considerable value as a stimulant and are used as a masticatory by the natives of the West Coast.

Two types of nuts exist which differ in colour and in flavour, the white being preferred to the pink. The former is consequently of much greater market value and commands four times the price of the latter.

As a result of this difference in price the Department of Agriculture determined, in 1910, to attempt to produce strains of Cola which produced only white nuts. It was found that while the majority of the existing trees produced pink nuts some produced white, and some both white and pink. White seed was obtained from various sources of trees bearing white nuts, and these were planted at the agricultural stations with the idea of keeping records of the individual trees and obtaining a supply of seed for future planting.

When these trees matured and bore fruit, very few gave white nuts entirely and some pink only.

No attempts at pollination of white by white were made, but seed from those trees bearing a large proportion of white were used for future planting. The original trials were made at the Aburi Botanic Gardens and Kibi Experimental Station and later extended to Asuansi, Hemang, Peki and Wiawso, but these later planted plots are not advanced sufficiently to deal with.

Records of eight years' yields are available from Aburi and Kibi, and from these it appears probable that the largest proportion of white nuts are produced by trees in full bearing, and that the ratio of white to pink increases up to that point. Later on the proportion falls again to the original ratio or nearly so.

The fact that the ratio increases is mentioned by H. F. MacMillan in his book "Tropical Gardening and Planting," page 382, and is fully borne out by the results at the above stations.

The Trials at Kibi.

The field at Kibi is composed of 9 lines of 21 trees, planted 30 feet by 30 feet, but only 168 actually were established. For the purpose of this paper, 24 of these are eliminated for the following reasons:—

(*a*) 11 died.

(*b*) 2 gave no crops.

(*c*) 10 gave white nuts only.

(*d*) 1 gave pink nuts only.

The average yield per tree is 246 nuts, of which 215 are white and 21 pink, or a ratio of 10·7 : 1, but the ratio varies in individual trees from ·2 : 1 to 897 : 1.

The mode or greatest frequency ratio occurs at 3·5 : 1. Practically every tree in this plot shows the tendency to prove the increase of the ratio of white nuts to pink mentioned above. It is impossible in the space available to reproduce the actual records of the individual trees so that the mean ratios have been incorporated in a graph (Plate XX) which shows the point in question very clearly.

For this purpose the trees have been grouped according to whether they cropped every year, every year but one, and every year but two.

This method was adopted in order to avoid the confusion which arises through trees not arriving at the peak of the curve together when, through probably external influences, they have failed to crop in one or two years.

This is clearly shown in the graph, but were the whole records graphed together, the numerous peaks for the different groups would mask the point to be emphasized.

It can be seen from a study of the figures that even in the case of trees which show yields in three scattered years, only there is a distinct tendency to this rise in ratio with a corresponding fall later.

The Trials at Aburi.

The field has six planting rows, with 12 trees in each, but only 68 trees were established. Fourteen of these are eliminated for various reasons:—

(*a*) 7 gave no crop.
(*b*) 4 gave white nuts only.
(*c*) 3 gave pink nuts only.

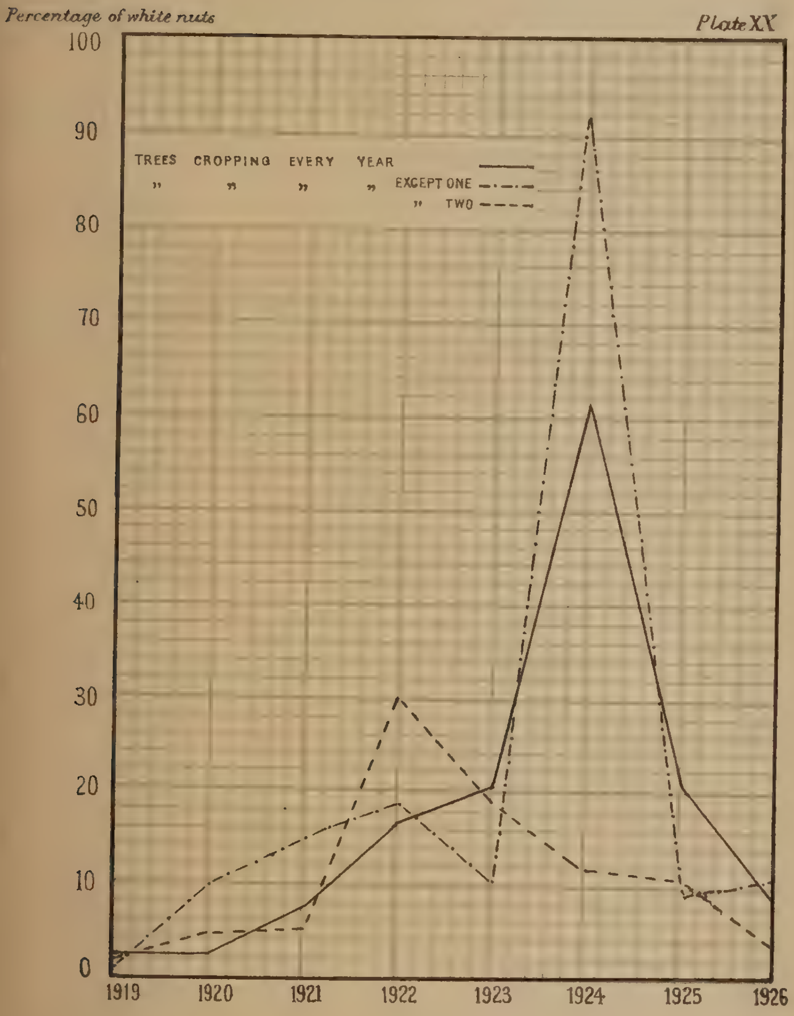
The same tendency as at Kibi is shown here, but as during 1921 and 1922, there was little or no crop, the graph from this station has not been considered to be worth reproduction, although it follows on the same general lines as that at Kibi. The ratio is not so wide as at Kibi and therefore the peak is not so marked, which may be accounted for possibly by differences in soil.

Since the increase in ratio of white nuts to pink appears, therefore, to be a function of age of the tree rather than a Mendelian character, it is obvious that attempting to breed a pure strain of white Cola by pollination of white by white parents would be futile. Other methods such as vegetative reproduction by cuttings and grafting will be equally useless from the fact that when a tree has reached a certain age the ratio will probably decline, no matter whether a tree is left alone or a scion taken from it and grafted into another.

It is, therefore, necessary that annual planting of white nuts be made in order that as many trees as possible may be at the peak of the curve at one time.

INDIVIDUAL COLA YIELDS AT KIBI SHOWING INCREASE OF RATIO OF WHITE NUTS TO PINK WITH AGE.

Plate XX



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PAPER No. XXI.

OIL PALM YIELDS ON CLEANED GROVES AT PEKI BLENGO.

By A. W. PATERSON.

The five-acre oil palm plot at Peki was in existence when the department opened this sub-station in 1913; the plot was cleared of bush and the palms cleaned during 1914 and 1915. The majority of the palms are now estimated to be 25-35 years old, and appear to be a good stand of palms. They were undoubtedly planted, but are not regularly lined out as in a plantation. Half of the plot has been thinned to 70 palms per acre, and in the other half there are fully that number to the acre.

The yields recorded from the five acres have been as follows:—

Year.	Number of bunches. (5 acres)	Weight of pericarp oil. (5 acres)
		lbs.
1916	223	544
1917	534	1,580
1918	629	2,224
1919	1,003	2,447
1920	307	801
1921	375	1,200
1922	735	2,803
1923	1,127	3,769
1924	589	2,078
1925	720	2,924
1926	428	1,653

The weight of pericarp oil has been calculated as follows:—

Fruit ... ... 50 per cent. weight of bunch.
Oil ... ... 25 per cent. weight of fruit.

The monthly distribution of bunches reaped since 1917 expressed as percentages of annual yield have been as follows:—

Months	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1917 ..	2·7	10·11	20·8	17·6	8·6	21·5	1·6	4·3	1·48	1·48	3·9	5·8
1918 ..	7·9	7·9	1·4	11·4	16·2	6·2	6·8	5·4	9·5	9·5	8·9	9·2
1919 ..	7·4	11·9	6·1	13·4	24·0	5·6	1·8	6·4	5·6	5·2	6·9	5·1
1920 ..	—	25·0	·9	—	—	23·1	2·6	4·5	21·5	5·9	8·1	8·1
1921 ..	2·9	15·4	22·1	14·9	9·9	7·7	6·4	1·86	2·4	4·2	9·07	6·1
1922 ..	11·2	14·0	9·1	16·1	10·2	8·3	8·7	5·4	4·9	7·2	3·8	1·3
1923 ..	8·3	9·5	2·6	26·4	12·06	5·7	3·5	5·4	8·4	10·1	4·4	3·6
1924 ..	7·5	35·4	12·0	18·8	—	—	8·4	6·2	7·1	2·3	1·8	—
1925 ..	1·6	12·5	15·8	13·3	25·1	8·7	1·25	—	5·3	2·9	3·0	1·6
1926 ..	12·6	14·0	10·9	17·5	11·1	—	—	—	11·1	14·4	7·9	—
Average	7·8	14·3	9·1	16·1	13·4	7·7	4·1	4·3	7·1	6·3	5·3	4·0

The graph (Plate XXI) shows the average monthly yields, expressed in percentages.

From this it is seen that the oil palm is in the main a two-season crop.

The main crop, which gives 39·5 per cent. of the total yield, extends from February to May and is followed by a smaller crop from September to November.

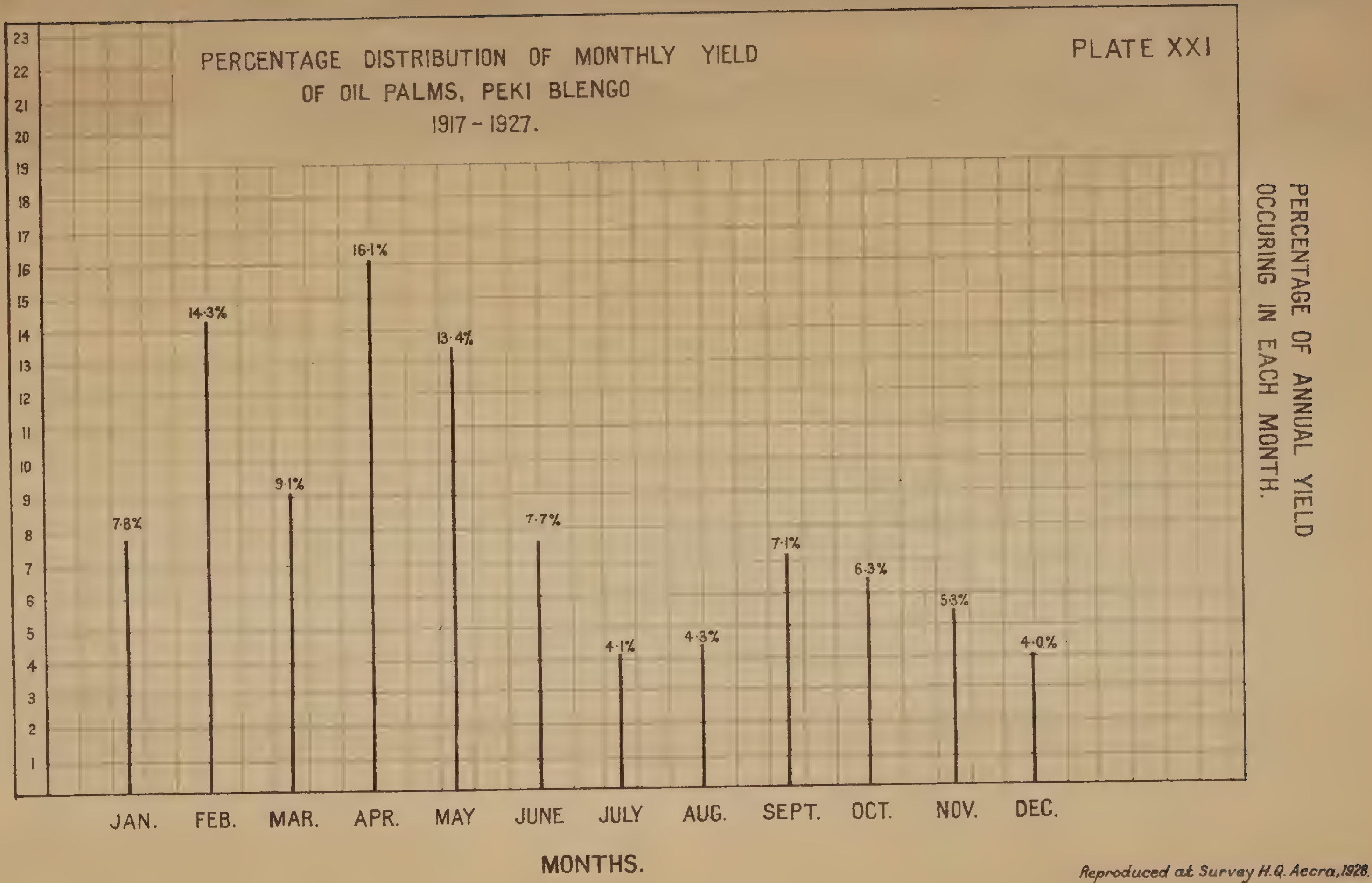
PLATE XXI
PERCENTAGE DISTRIBUTION OF MONTHLY YIELD
OF OIL PALMS, PEKI BLENGO
1917 - 1927.
PERCENTAGE OF ANNUAL YIELD
OCCURING IN EACH MONTH.
7·8%
14·3%
9·1%
16·1%
13·4%
7·7%
4·1%
4·3%
7·1%
6·3%
5·3%
4·0%
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS.
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PAPER No. XXII.

ACCRA SISAL PLANTATION DURING 1926-1927.

BY J. E. SYMOND, *Superintendent.*

The previous article in the Year Book for 1926 summarized the working of the plantation and factory to the end of the first half of the financial year, 1925-26. The most convenient form in which to publish a further summary of the progress of the plantation is to give in detail the results of the working year, April, 1926—March, 1927, and a brief reference to the working from April—September, 1927.

During the whole period the plantation has suffered from a very severe drought, the rainfall in 1926 being the lowest ever recorded (10 inches). This must naturally affect the replanting. A shortage of leaf has been experienced in 1927, partly due to the prolonged drought and in part to the fact that the acreage of mature sisal has been found insufficient to keep the existing factory working to capacity. Steps have been taken to increase the acreage.

Results.

The results of the working year, April, 1926—March, 1927, are shown in Appendices A and B, which give details of output and cost of production. From these it will be seen that a production of 459 tons fibre was achieved, as compared with 285 tons in the previous year. The cost of production per ton fibre was £17 6s. 7d., a substantial decrease on previous figures. As men become more efficient and production increases, a decrease has been shown in every item of production cost.

Transport charges have been materially reduced by the installation of a Fordson tractor for haulage. This machine is fitted with heavy solid double tyres and straddles the railway lines. It has proved very powerful and most efficient.

During the period, April—September, 1927, it has only been possible to work for three months, owing to the shortage of leaf. The output has been 111 tons at a cost for production of £15 12s. 2d. The results are tabulated in Appendix C. The decrease in production cost is principally due to the absence of one European under the heading "Supervision." The fibre was sold locally under a system of tenders, and market and shipboard charges are therefore eliminated.

Prices Realised.

The year, April, 1926—March, 1927, closed with a falling market, but prices realised during the period averaged £40 per ton. This is an increase on previous figures and is due to the installation of new machinery for brushing and baling, which have bettered the quality and packing of the fibre.

As the product became known on the home markets, it became possible to enter into a system of forward sales, which reduced marketing charge by some £2, by avoiding heavy landing and sampling costs.

Average shipboard and market charges were £5 10s. per ton, of which £4 16s. is for Ocean Freight. Details of the charges are as follows:—

Nature of Charge.	Cost per ton fibre.
	£
Brokers' Commission 1%	·38
Landing and sorting	·23
Port rates	·008
Rent and showing	·08
Insurance	·04
Interest on charges	·002
Petties and postages	·003
Ocean freight	4·80
	£5·543

Total revenue for the period, from fibre produced, was £14,965, as against a production expenditure of £7,954, leaving a profit of £7,011, from which to pay interest and depreciation charges. A net profit of £3,663 was realised.

Pests and Diseases.

There has been a slight recurrence of the physiological disturbance, "Sun Scorch," previously recorded. It occurs when very hot weather follows heavy rain and quickly ceases under normal conditions. Leaves affected are generally useless for decortication.

Experimental Area.

A plot of 40 acres of sisal was planted in 1925 with the object of testing the effect of reduced weeding. This plot has now received three weedings in the first two years of its life, and will not be cleaned again till after harvesting. It is healthy and well-grown and demonstrates that unless abnormal wet seasons occur, this amount of weeding is sufficient for sisal before coming into bearing.

Yield.

Percentage fibre in the leaf has remained constant at 3·4 per cent. From the commencement of harvesting to the present date, 800 acres of mature sisal have given a yield of just over 1,000 tons, equal to 25 cwts. to the acre. Poling, as usual with this crop, is very irregular, and it is as yet too early to forecast the total yield per acre.

APPENDIX A.

Accra Sisal Plantation and Factory.

SUMMARY OF PRODUCTION AND COST FOR PERIOD
1ST APRIL, 1926 TO 31ST MARCH, 1927.

Month	Number of Working Days.	Cwts. of Fibre produced.	Expenditure. £ s. d.
1926			
April	21	800	706 8 11
May	21	760	702 2 2
June	23	780	674 9 10
July	24	800	759 8 6
August	23	660	718 16 11
September	23	820	653 8 10
October	25	800	623 10 1
November	24	760	642 8 10
December	23	760	614 17 4
1927			
January	23	760	578 10 10
February	20	740	582 5 8
March	25	740	625 7 2
TOTALS	275	9,180	£7,881 15 1
Spares and Replacements not charged to any one month			73 0 10
Monthly average	22·91	765	£7,954 15 11

Average Output of Fibre per Working Day of 9 hours .. .. .. 33·38 cwts.
Factory and Plantation Costs of Producing 1 ton of Fibre £17 6 7

APPENDIX B.

Accra Sisal Plantation and Factory.

ANALYSIS OF PRODUCTION COSTS FOR THE PERIOD
1ST APRIL, 1926, TO 31ST MARCH, 1927.

Head of Expenditure.	Total Expenditure for 18 months.			Expenditure per ton Fibre
	£	s.	d.	£
European and African Salaries, Passages and Allowances :—				
Total Supervision	1,420	0	0	3·10
Labour—Cutting leaves	1,448	16	1	3·16
,, Transporting leaves	349	9	7	·76
,, Decorticating and refuse ..	594	5	8	1·29
,, Brushing fibre	344	2	10	·76
,, Drying fibre	330	16	3	·72
,, Grading and hanking	300	7	9	·65
,, Baling, packing and marking ..	138	17	5	·30
,, Plantation roads, etc.	783	4	6	1·70
,, Stumping and clearing	162	4	6	·35
,, Engine	51	15	6	·11
,, Recruiting	273	8	3	·60
Total Labour	4,777	8	4	10·40
Total labour and supervision	6,197	12	4	13·50
Materials—Fuel, oil	534	16	9	1·17
,, Lubricants	157	5	5	·34
,, Petrol and kerosene	170	13	10	·37
,, Baling wire	44	7	6	·10
,, Baling canvas	76	5	9	·17
,, Grease and waste	9	12	8	·02
,, Miscellaneous repairs, buildings	119	16	1	·26
Extra Freight, storage and cranage ..	228	7	3	·49
,, Water	342	17	6	·74
,, Spares and replacements	73	0	10	·16
Total materials and extra	1,757	3	7	3·82
Total labour and supervision	6,197	12	4	13·50
Grand Total	£7,954	15	11	£17·32

Total Output of Fibre .. 459 tons.

APPENDIX C.

DETAIL AND COST OF PRODUCTION.

JUNE–AUGUST, 1927.

Month.	Fibre produced.	Days worked.	Expenditure.
	Cwts.		£ s. d.
June	860	26	633 0 0
July	760	25	551 19 1
August	600	22	547 14 3
	2,220	73	1,732 13 4

Average production per working day .. 30 41 cwts.
Average cost production per ton .. £15 12s. 2d.

ANALYSIS OF PRODUCTION COST.

Item.	Cost per ton.	
	£ s. d.	£
European supervision	1 11 8	1·58
Cutting leaf	3 2 1	3·10
Transporting leaf	0 14 3	·71
Decorticating	1 2 8	1·13
Brushing fibre	0 17 6	·87
Drying fibre	0 13 2	·65
Sorting and hanking	0 10 1	·50
Baling	0 4 4	·21
Plantation, roads, etc.	1 11 1	1·55
Stumping and clearing	0 6 2	·30
Engine	0 1 7	·07
Recruiting	0 12 5	·62
Overseer, headmen and office ..	0 14 0	·70
Materials :—		
Fuel oil	1 11 0	1·55
Lubricating oil	0 6 7	·32
Petrol and kerosene	0 6 5	·32
Baling wire	0 3 6	·17
Baling canvas	0 3 4	·16
Grease and water..	0 0 6	·02
Miscellaneous	0 5 9	·28
Local freight	0 0 8	·03
Water charges	0 13 5	·67
	£15 12 2	£15·608

PAPER No. XXIII.

DISTRIBUTION AND YIELDS OF SHEA BUTTER-NUT TREES IN THE NORTHERN TERRITORIES.

BY G. C. COULL.

The Shea butter-nut tree is botanically known as *Butyrospermum Parkii*, and belongs to the Natural Order Sapotaceæ (Dagomba *Tanga*, Hausa *kadanya*.)

Appearance of the Tree.

In the wild state, on land which shows no signs of having been cultivated, and which is swept by bush fires year after year, the tree rarely grows to a great size and is twisted and stunted; the girth is seldom more than 24 inches and the height seldom more than 20 feet. On land which is cultivated for a few years, and then reverts to bush, the tree is of greater size, and this is probably due to the few years of protection thus afforded from fire. In and around villages, where the tree is never subjected to a bush-fire, the tree grows to greater dimensions and trees up to 69 inches in girth and 50 feet in height may be seen.

The bark is deeply fissured vertically and horizontally, making square scales of great thickness. This scaling extends to quite small branches.

The leaf is from 9 ins. to 10 ins. in length, stalked, simple, entire, oblong and glabrous; the stalk taking up from $2\frac{1}{2}$ ins. to $4\frac{1}{2}$ ins.; the width is from $1\frac{1}{2}$ ins. to 3 ins. The leaves are shed each year, but the tree does not remain long without them. Leaves may be shed before, with, or after flowering and in the last instance there is no distinct period when they are without leaves.

The flowers are borne in globular corymbs, at the extremities of the branches, 2 to 3 ins. across. Sometimes flowers alone, sometimes flowers and leaves, are borne at the extremities. Each flower is creamy white, and slightly scented. Calyx 8 to 10 partite, Corolla 5 to 6 lobed. Stamens same number as or more than petals. Ovary superior, 1 to 5 celled, but commonly 1 to 2 celled; ovules solitary in each cell; fruit a berry.

The flowers are usually few in number if new leaves are produced before flowering, and a small yield of fruit is obtained. Flowers are borne from December to March. The fruit varies considerably

in size and appearance; they are round and long. The long fruit is noticeably pointed at the tip whereas the round fruits are blunt. Fruit is borne from May to August.

Natural Distribution and Habitat.

The distribution of Shea is widespread in the Protectorate. On marsh it is non-existent, and on land subject to flooding it is rarely found. The characteristic habitat is the upper slopes of the undulations which form such a noticeable feature of the country. The tree is a light-lover, and does not flourish under shade. Where such trees as *Afzelia africana*, *Isoberlinia* spp., and *Paradaniellia Oliveri* grow, it is not found. It occurs sometimes in almost pure stands of varying density.

The distribution of the tree is largely influenced by the density of the population, and by the pursuits of the people. The tree, being indigenous to the country, is found at its densest where there are neither farms nor villages. On old farmed land the trees are fewer, but larger; fewer because many have been cut out in the process of making the farm, and larger because they have been protected from the bush fires. Round the villages there are few trees, as they have been gradually cut out for timber, firewood, medicine, etc. Hence it is that, generally, the density of shea tree is inversely proportional to the population.

Pests and Diseases.

No fungoid pests have been noted. Insect pests are not numerous. A large caterpillar of *Cirina Butyrospermii* feeds on leaves and sometimes completely defoliates the tree attacked. The adult flies in May and the larva matures in September. After feeding on the trees, it pupates in a cleft at the base of the tree.

The larvæ of *Mussidia Nigrivinella* attack kernels if badly stored, but they are very easily controlled, and of no economic importance. Loranthus is prevalent in some districts, especially in the North West.

False Shea Nut Tree.

The tree *Lophira Alata*, Banks. Dipterocarpaceæ (Hausa, namijin kadai; Dagomba, kultanga), is known amongst natives as the false shea-nut. The only resemblance between this tree and the true shea-tree is in the leaves, the flowers and bark being quite dissimilar to those of *Butyrospermum*.

The *Lophira* is not common in the Northern Territories, and grows only in certain localities, usually on the banks of a river. The writer has seen specimens of this tree on the Dakar river only, where the Salaga-Krachi road crosses it.

Description of Trials at Yendi.

Investigations were started in March, 1922, when a 20-acre reservation was chosen on ground which had not been farmed, and was marked out as follows:—

SECTION A.	SECTION Z.	
7·71 acres Unweeded.	B. 3·04 acres.	C. 3·18 acres.
2·52 acres Weeded.	D. 2·72 acres.	E. 3·09 acres.

Section A was divided into a weeded and an unweeded portion and was burned. Section Z was divided into plots B, C, D and E and boundaries were fire-traced to prevent burning at the wrong time. Each plot has been burned once a year since, starting as soon after the rains as the grass was capable of being burned. Plot B is burnt first, C, D and E at successive intervals of 10 days with the idea of finding therefrom the effect of the time of burning on the yield of fruit.

Increase in Girth of Trees.

The girths of 20 trees on each of plots of A and Z were taken, and these measurements have been kept from year to year.

Girths of trees are shown in Table I.

TABLE I.

Year.	Yendi Unburned Plot.		Yendi Burned Plot.	
	Average Girth. Inches.	Increase. Inches.	Average Girth. Inches.	Increase. Inches.
1922	21·28	—	16·47	—
1923	21·36	·08	16·55	·08
1924	21·72	·36	16·90	·35
1925	22·12	·80	17·47	·57
1926	22·24	·26	17·78	·31
1927	22·38	·14	18·01	·23

In 1926, one tree died before girths were measured.

From the above figures it will be seen that the annual increase in girth is very small, and that the tree is exceeding slow-growing.

Yields of Kernels Per Acre at Yendi.

Owing to the difficulty of collecting the crop on the unweeded portion of A, and also to the fact that it was burned by some passer-by on two occasions, the yields were discontinued as being inaccurate; the weeded portion of A was kept as a control to plots B, C, D and E.

Yields of kernels are shown in the following Table II:—

TABLE II.

Plot.	Acres.	No. of Trees on Plot.	Trees per Acre.	Yields per Acre (Kernels, in Pounds).				
				1923.	1924.	1925.	1926.	1927.
A (weeded) ..	2·52	489	194	103·9	80·1	64·3	93·5	49·6
B (burned) ..	3·04	404	133	11·2	53·3	92·4	31·7	11·8
C " ..	3·18	473	149	39·3	29·7	75·5	37·7	13·4
D " ..	2·72	305	112	2·6	54·6	100·7	38·3	22·1
E " ..	3·09	585	189	—	17·4	44·6	21·3	15·2

From a study of Table II some useful facts are evident. The unburned, but weeded plot A consistently gave higher yields than the burned plots, except in the year 1925. As this plot was kept clear of undergrowth, no difficulty was experienced in collecting the fruit.

For the 1923 crop the burning did not begin till January. Plot C, however, was accidentally burned in December 1922, and gave the best yield. Plot E, which was in full flower when burned, gave no yield at all. It was generally considered at the time that burning was too late, and this was borne out by the yields obtained.

For the following years burning was commenced, as soon after the rains as the undergrowth was sufficiently dry to burn, which was usually the first few days in December, and continued at 10-day intervals. The greatest yield has been obtained in each case with plot D, which is burned 20 days after plot B or between the 19th and 24th December, and for the Yendi district this seems the optimum time.

Conclusions Drawn from Trials.

The conclusions drawn from these experiments are:—

(*a*) Burning should take place within 20 days after it first becomes possible.

(*b*) Premature burning increases the difficulty of collection, but the yield is good.

(*c*) Late burning, by destroying flowers, and such fruit as is set, causes practically total loss of crop.

(*d*) By the total prevention of burning, the maximum yield is obtained, but the increase in the cost of collecting the fruit would be so large as to prevent it being economically possible, apart altogether from the fact that it would be quite impracticable to prevent burning over even a small protected area.

The natives say that the shea-butter tree yields in a cycle of three years, in the sequence good, medium, poor. This has not been confirmed yet, though this sequence has been found during the first three years of the experiment.

Rainfall and Yields.

The rainfalls and yields are given in Table III.

TABLE III.

Crop-Year. (Jan.—Dec.).	Plot A. Pounds Kernels per Acre.	Rainfall.	
		For Seven Months (Jan.—July) of the Crop-Year.	For the Year (Jan.—Dec.) before the Crop Year.
1923	103·9	32·30	43·93
1924	80·1	27·66	49·68
1925	64·3	23·04	67·10
1926	95·5	23·09	46·12
1927	49·6	23·76	43·92

There seems to be no correlation between total amount of annual rainfall and total annual yield within the limits occurring during these years, but marked periodic variations in the yields occur, as is usual in permanent plants under no cultivation. A violent tornado may cause a great deal of damage by destroying fruits which have just formed.

Estimate of Supplies available.

An estimate of the potential supply of shea-butter in the Northern Territories is given in Table IV.

TABLE IV.

District.	Square Miles.	Production Area Square Miles.	Density of Shea Trees.	Average Yield Kernels per Acre	Total Yield Kernels	Amount of Kernels Used by Population.	Balance of Kernels for Export	Population.	Population for Collection Women.	Amount Capable of Collection
				Lbs.	Tons.	Tons.	Tons.			Tons.
Lawra-Tumu	3,533	2,317	51	28	18,536	3,644	14,892	82,967	11,852	8,889
Wa	3,540	3,186	41	27	25,000	1,848	23,152	42,076	11,840	8,880
Northern Mamprusi ..	2,400	480	6	94	12,877	8,457	4,420	192,510	27,501	20,626
Kussassi	790	527	8	18	4,063	2,152	1,911	49,013	7,002	5,251
Southern Mamprusi ..	2,000	1,000	61	27	7,714	557	7,157	12,774	1,825	1,369
Western Dagomba ..	4,800	4,300	63	48	58,971	3,466	55,505	78,961	11,280	8,460
Western Gonja	8,450	4,000	8	6	6,857	869	5,988	19,737	2,819	2,114
Eastern Gonja	3,800	2,600	31	24	17,828	576	17,252	13,132	1,876	1,407
TOTAL	29,313	18,410	—	—	151,846	21,569	120,277	491,170	75,995	56,996

In the above table it will be noted that the " production area " amounts to 63 per cent. of the total area of the Protectorate. The mandated area is not taken into account.

The " density of trees " is arrived at by taking the mean of counts in the various districts.

Estimates of the " Average yield of kernels " are expressed as lbs. per acre, irrespective of the number of the trees, this being regarded as more accurate than basing estimates on yields. The results from the Northern Province were determined by political officers by actual weighing, but in the Dagomba and the two Gonja Districts the figures were calculated from the results obtained from the Yendi trials.

"Amount of kernels consumed," and " Balance for export," are determined by assuming that a family of five consumes $10\frac{1}{4}$ lbs. of shea-butter per month, and 25 per cent. of butter is obtained from the kernels.

" Population available for collection " is based on the assumption that the number of able-bodied women is one-seventh that of the total population. The Commissioner of the Wa District, however, supplied the figures for his District, which include all females over six years of age.

The " amount capable of collection " is obtained on the assumption that one woman in a season of 90 days will collect 15 cwts. of kernels. The reason is given below. It will be noted that the women of Kussassi and Northern Mamprusi, whilst capable of collecting 5,251 and 20,626 tons of kernels respectively, have only 1,911 and 4,420 tons to collect.

Figures are not available to the exact volume of existing exports of shea-butter to Ashanti and the Colony. Assuming, however, that it is equal to the internal consumption, the balance available for export is 98,708 tons of kernels. As, however, native methods only yield 25 per cent. of butter, whereas by extracting by solvents 50 per cent. could be obtained, it will be seen that the existing local need would be met by half these quantities were a factory established in the Protectorate, and the fat available for export would be 65,138 tons per annum. With the existing native methods, however, the balance would be 98,709 tons of kernels or 24,677 tons of fat.

DIFFICULTIES OF CENTRALISATION.

The harvesting of the crop under the existing distribution of the population must be now considered. At present the industry is entirely in the hands of the women, and if the figures for available women are correct, the total amount of kernels that could be collected would be 56,996 tons. (This is calculated as follows:— The fruiting season lasts from the middle of June to the end of September—say 90 days. Each woman collects a load of

60 pounds of fruit per day, a total for 90 days of 15 cwts. of kernels). From this total of 56,996 must be taken 3,340 tons and 16,206 tons on account of Kussassi and Northern Mamprusi Districts respectively, leaving under present conditions 40,450 tons of kernels to be collected by the villagers scattered throughout the whole of the Protectorate.

On account of the sparse distribution of the trees, women have in many cases to go long distances from their villages to get the fruits, and at present they merely collect enough for making shea-butter for their own use, and for supplying itinerant traders.

A trading firm in Kumasi sent a representative here during the past season to buy kernels, and offered 1s. 3d. per tinful (equal to £5 per ton of kernels), and could get only a few tons. Itinerant traders are able to pay prices much in excess of the market value on the spot, and yet makes good profits in Ashanti and the Colony. The price in Kumasi is usually three times that in Tamale.

As time is of no object to a native, he always thinks of the value of shea-kernels as being that of the price of the shea-butter capable of being extracted therefrom. A kerosene tinful of kernels, weighing 27 lbs., therefore, would be valued at 7 lbs. of shea-butter, which is about the amount capable of being extracted by their own methods.

The fact that the industry is entirely in the hands of the women is against it, and men cannot be induced to go out and collect the fruits.

SUMMARY.

Summarising this report we see that:—

(*a*) The present production is entirely in the hands of the women, and this is probably a great factor against the establishment of an industry in kernels.

(*b*) Added to this, we have the fact that the native, time being no object to him, would like the same price for the kernels as the price of the fat extracted from the kernels.

(*c*) The estimated crop of kernels used is 21,569 tons kernels, and the estimated export as the same amount, making a total of 43,138 tons of kernels used annually.

(*d*) The annual yield could be increased by careful control of burning, but as the densest areas are away from villages, this is exceedingly difficult.

(*e*) The amount, 40,450 tons of kernels, capable of being collected, would be scattered throughout the whole of the Protectorate.

(*f*) The potential supply is 120,277 tons of kernels, and it is quite evident that large quantities go to waste each year.

PAPER No. XXIV.

PREPARATION OF LEAF COMPOST AS A MANURE FOR THE DENUDED SOILS OF ACCRA.

By C. H. KNOWLES and J. M. DUNBAR.

The land which forms the residential area of Accra was originally of exactly the same character as what is known as the Accra plains—being covered with coarse grass and shrubs with here and there a few stunted trees.

The real soil is thin and not rich, vegetable matter being destroyed by fires, which in the plains generally are of annual occurrence. In a natural state, the soil has reached a condition of balance, its quality being just sufficient to maintain the coating of grass and shrubs.

When the land was taken for building purposes, the grass, shrubs and trees were cleared away. Lines of ornamental trees were used as an edging for the bungalow sites and roads were constructed. Drainage was confined to the sides of most of the roads.

When the bungalows were occupied, the development of the compounds was a matter for the occupants. Dhoub grass was planted in many compounds and at first thrived, but unless regularly watered this grass died out completely.

LOSS BY DENUDATION.

From the time the original clearing was made, the soil has been subjected to regular denudation. Every shower of rain washes away some of the soil, and the daily sweeping up of fallen leaves by the sanitary gangs is responsible for much more serious denudation. In one compound of approximately one acre in 1926 over 400 cubic feet of fallen leaves were collected in eight months. Normally this would have been destroyed by sanitary gangs, but actually the experiment was tried of using it as manure and it was buried in garden beds. When it is remembered that the soil was poor to start with, it is not surprising to find that under a few years of unrestrained tropical showers and the organised efforts of sanitary gangs, the surface soil is entirely removed and the raw sub-soil exposed. This is quite unsuited for grass,

PLATE XXII.

COMPOST SHED IN ACCRA.

hedges, shrubs and flowers, and needs special preparation to fit it for garden purposes. This preparation consists of adding to the soil organic matter in the form of humus.

Primarily when humus was required the only way to get it was to leave heaps of vegetable matter on the garden to decay—a process objected to by the Sanitary Authorities—or the sweepings of the garden were used at once, not a very effective method as the decay is slower.

PREPARATION OF COMPOST.

Mention has been made of the very considerable quantity of vegetable matter obtained every year from a compound, and up to the present all this has usually been burnt and so entirely wasted.

In order to facilitate the use of this material in the soil and to prevent the waste, a special building was erected at the Accra Horticultural Nursery for the purpose of converting it into humus. The sanitary side of the question—the breeding of flies, etc.—had of course to be considered and the only alternative was a fly-proof building. The building which has been erected is a trial one and if it is successful similar buildings can be constructed at the major stations of the Department.

The building consists of a concrete tank 12 ft. by 12 ft. by 3 ft., surmounted by walls 10 feet high of mosquito proof gauze covered over by a roof of wood and felt. The floor is concrete with a slight fall towards the door of the building draining into a sump measuring 3 feet cube. A photograph of the building is given (Plate XXII) showing tank, mosquito proof meshing, sump and cover, etc. Part of the finished compost of the last charge can be seen outside the building.

The principle of the compost heap is the decomposition of vegetable matter to which has been added soil and lime. The method adopted here for charging the compost tank is as follows: First, a layer of refuse is put in, this is covered with a thin layer of soil on top of which is placed a very thin layer of lime. This procedure is repeated until a height of about three feet has been reached, and the whole is then covered over with a fairly thick layer of soil. Water is added until the whole charge is moist, which condition should be maintained throughout the period of decomposition.

It has been found that the watering, which is done about once a week, can be satisfactorily carried out with a hose. The drainage from the sump is returned from time to time to the material in the tank. From three to four months is required for the process of decomposition depending upon the kind of material employed. After being allowed to decay for two or three months, the heap should be turned over. Each charge of the tank provides about 10 tons of valuable manure (432 cubic feet at approximately 55 lbs. per cubic foot).

FUTURE TRIALS.

A supply of Standard Adco has been ordered in order to speed up the process of decomposition. Adco is a fine powder which embodies late scientific discoveries. Its function is to create the ideal conditions which cause the useful bacteria to work and also to increase the amount of plant nutrients. An article on the value of this synthetic preparation appeared in " The Tropical Agriculturist," Vol. LXVII., No. 6, December, 1926.

Organic matter has been long recognised as an important constituent of soil; it breaks up stiff clays, gives cohesion to sandy soils and increases moisture-holding capacity. It also provides valuable food material to plants. Its use as an addition to the impoverished soils of compounds in Accra is absolutely essential to enable such soils to be used for ordinary garden purposes.

For the best effects the humus should form part of the whole depth of soil likely to be reached by plants in the garden bed.

PAPER No. XXV.

METHODS OF SOIL SAMPLING AND SOIL ANALYSIS RECOMMENDED PROVISIONALLY FOR USE IN WEST AFRICA.

Following is the report submitted to the West African Agricultural Conference by the Chemical Committee of the Conference. The Departmental Chemists forming the Committee were: DR. F. J. MARTIN *and* MR. H. C. DOYNE *of the Sierra-Leone Department;* MESSRS. A. C. BARNES, C. H. WRIGHT *and* E. DE B. DIAMOND *of the Nigerian Department:* CAPTAIN R. COULL *of the Gold Coast Department.—(Editor.)*

The Committee took the methods put forward by Messrs. F. J. Martin and H. C. Doyne (Sierra-Leone Department) as a basis for their discussions and the following methods of sampling and examining soils were recommended for provisional use, the whole question to be reviewed at the next West African Agricultural Conference.

2. Determinations Necessary for Soil Characterisation.

The Committee discussed the question as to what determinations were necessary for characterising the soil type. It was thought that certain determinations were essential in soil analysis, but that others, although very desirable, could not always be carried out owing to lack of time. It was decided therefore to agree as to what determinations were essential and to leave the chemist on the spot to supplement these by whatever additional determinations he thought necessary.

It was agreed that when examining soils for the purpose of soil survey the following determinations were necessary:—

(1) Mechanical analysis (including amount of calcium carbonate where present).

(2) Organic carbon in first foot.

(3) Acidity or alkalinity expressed as pH values.

(4) Total nitrogen on soil types.

(5) Analysis of the clay fraction of definite soil types. This analysis to include determination of silica, alumina, iron and combined water.

Other determinations, such as soluble salts, lime requirement, phosphate, potassium, nitrate, etc., yield valuable information, but for the time being are not included in the list of essential data. It should be left to the discretion of the chemist to decide what determinations are required to supplement those given in 1—5 above.

3. Methods of Sampling.

It was decided that the instructions with respect to sampling given in the Appendix of the paper, should be circulated for the information and use of the agricultural and forest officers who might be interested in taking and submitting samples. It was realised, however, that a certain amount of latitude should be allowed in the taking of samples and that where suitable conditions prevail—*i.e.*, the soil is not too stony, hard or sandy— and suitable tools are available, there is no reason why such tools should not be used. All that is necessary is to ensure that the section is vertical and that the sample does not include more from one horizontal layer than another. There is, however, one advantage in digging the actual holes, and that is the digging can be done by a native and the soil profile down to four feet is fully exposed, and this often yields valuable information. It was agreed that photographic records of soil profiles should be taken where possible.

4. Classification of Soil Particles.

As a preliminary to discussing mechanical analysis the classification of soil particles was considered. It was thought that within limits the number of soil separates should be kept as low as possible. The classification considered as a basis of discussion had the objection that it did not correspond with that recommended by the Committee of the Agricultural Education Association, but by very small alterations it was made to do so.

The classification recommended is as follows:—

A. "Stones and gravel"—all particles greater than 1 mm.

B. "Fine earth"—all particles less than 1 mm.

All further mechanical and chemical analysis are made on, and expressed as percentage of, the "fine earth."

The fine earth is divided into the following fractions:—

Coarse sand less than than 1 mm. but greater than ·2 mm. in diameter.

Fine sand less than ·2 mm. but greater than ·04 mm. in diameter.

Silt less than ·04 mm. but greater than ·002 mm. in diameter.

Clay less than ·002 mm.

If the silt should form a large proportion of the "fine earth" and it should be considered necessary to separate this fraction further, then the following fractions are recommended:—

Coarse silt between ·04 and ·01 mms.

Fine silt between ·01 and ·002 mms.

5. Methods of Mechanical Analysis.

It was decided to carry out mechanical analysis by the beaker method of sedimentation, as this was the more suitable method for native assistants to use*. Further, that all determinations should be made on the oven dry (105° C.) soil, as in West Africa the moisture in air-dry soil varies greatly from the wet to the dry season, there being a big difference between the relative humidity of the atmosphere during these seasons.

(*a*) *Preliminary Acid Treatment.*—It was decided that preliminary acid treatment, where necessary, should be used to bring the method into line with that recommended by the Committee of the Agricultural Education Association. Actually, none of the chemists in West Africa had yet found a soil containing appreciable quantities of calcium carbonate.

(*b*) *Treatment with Hydrogen Peroxide.*—This was thought unnecessary owing to the low humus content of the soils, the instability of hydrogen peroxide in the tropics, and the undue lengthening of the process of mechanical analysis.

(*c*) *Deflocculator.*—Either ammonia or sodium carbonate.

(*d*) *Method of Extracting Fractions.*—The fractions to be expressed on an "ignited" basis, but the clay fraction to be expressed both "oven dry" and ignited. This conclusion was reached in view of the fact that the Agricultural Education Association Committee recommended the "ignited" basis, but Dr. Martin produced evidence, recently obtained, to show that the "ignited" basis might involve considerable error, especially with lateritic soils which are common in West Africa.

(*e*) *Loss on Ignition.*—This determination still to be made on a separate 1 mm. sample.

(*f*) All results to be recorded as percentages on the "oven dry" soil.

6. Organic Carbon.

The following methods were considered suitable:—

(*a*) *Dry combustion.*—Total carbon is determined as follows:—

A weighed portion of soil (about two grams) is ignited in a combustion tube in a current of carbon dioxide free air and the carbon dioxide given off, after passing over heated copper oxide and through a drying column, is collected in potash bulbs and weighed. This gives accurately the amount of carbon in the soil.

The apparatus found most efficient is an electric tube furnace such as is made by Messrs. Gallenkamp & Son. It is clean, does not heat the

**Note.*—This does not exclude the use of depth concentration methods (*e.g.*, Robinson's method) when the analyses are carried out by a competent chemist.

room unduly, and the temperature of the various parts of the tube can easily be controlled. With this apparatus, half-a-dozen determinations can easily be made during the day.

Inorganic Carbon.—Can be determined either by the Schrotter apparatus or by means of the following method. A flask of 300 c.c. capacity is fitted with a stopper through which passes a dropping funnel and a glass tube. The glass tube connects with two tubes containing fused calcium chloride and then passes into potash bulbs containing a fifty per cent. solution of potassium hydroxide. After the potash bulbs comes a small U tube containing solid potash and another containing fused calcium chloride. A weighed quantity of soil is placed in the flask with a little water, dilute sulphuric acid is run slowly on to the soil through the dropping funnel. The rate of evolution of the carbon dioxide should be about two bubbles a second as it passes the potash bulbs. When the evolution of the gas has ceased the remainder of the acid is run in and the flask gently heated. A current of air is drawn through the apparatus by means of an aspirator, the mouth of the dropping funnel being guarded by a small soda-lime tube.

Organic Carbon.—The organic carbon is determined by subtracting the inorganic carbon from the total carbon.

In Sierra Leone soils there is practically no inorganic carbon and the soil is acid. Where this, on testing, is found to be the case, the figure for total carbon can be taken as organic carbon. This simplifies the analyses considerably.

(*b*) *Method described by Sir Francis Watts in the West Indian Bulletin, Vol.* 12, 1912, *page* 70 :—

About two grammes of very finely powdered soil, or as much as may be expected to yield about 90 to 100 c.c. of gas are placed in a small flask of about 50 c.c. capacity having a side tube in the neck. (Wurtz flask.) To this, 10 c.c. of concentrated sulphuric acid are added and mixed by gently shaking. The flask is now attached, by means of the side tube and a piece of stout rubber tubing, to a suitable apparatus for measuring gas described below. When first attached the flask is brought into such a position that the neck is horizontal, a platinum boat containing chromic anhydride is placed in the neck, and the neck closed by means of a rubber stopper, care being taken that the neck is not soiled during the introduction of the chromic anhydride, so as to ensure that none comes in contact with the rubber stopper. While in this position, the apparatus is allowed to assume the temperature of the air; when this is accomplished, the gas-measuring apparatus is adjusted.

The gas-measuring apparatus consists of a nitrometer with a three-way cock connected with a reservoir of mercury and a manometer tube. To adjust the apparatus, the nitrometer is filled with mercury by raising the mercury reservoir while the nitrometer is in communication with the outside air through the appropriate channel of the stop-cock. The flask is now also brought into communication with the outside air by means of the stock-cock : thus the contents of the entire apparatus are at atmospheric pressure. The flask is now brought into communication with the measuring apparatus, by a proper turn of the stop-cock. The flask is then brought into a vertical position whereby the chromic anhydride falls into the flash; this is brought into intimate contact with the soil and acid in the flask by gently shaking, whereupon gas is at once given off. The flask is now immersed in a bath of boiling water to complete the reaction, and is agitated occasionally; in about twenty minutes the evolution of gas ceases, the hot water bath is removed, the apparatus allowed to resume the temperature of the air, the mercury levels in the measuring apparatus accurately adjusted and the volume of gas evolved measured. This volume is simply that found in the measuring apparatus, and is independent of that contained in the flask and its connections, which remains constant.

From the volume of the gas evolved after correction for temperature and pressure, the weight of carbon is easily calculated.

7. Acidity or Alkalinity (pH).

The Committee thought that this might be determined either electrometrically or colorimetrically at the discretion of the chemist. Where colorimetric determinations were made they should be checked in a few instances by electrometric determinations. The Committee also thought that no good purpose would be served by tying down the chemist to a particular method to be followed when making pH determinations, but they considered that the strength of the soil/water extract or suspension warranted consideration when determining hydrogen-ion concentration.

As a general rule it was agreed that a soil/water ratio of 1/5 was suitable and that the time of extraction should be one hour. It was pointed out, however, that a soil/water ratio of 1/5 was not always suitable and the case of Sierra Leone soils was instanced. Here a 1/5 extract indicated a nearly neutral or only faintly acid soil, while 1/1 extract indicated a distinctly acid soil which was corroborated by a high "lime requirement." The Committee therefore agreed that while 1/5 soil to water ratio might be regarded suitable concentration, yet if the pH values yielded by other concentrations indicated that the 1/5 extract was giving unreliable results, adaptations of the proportions of soil to water should be made at the discretion of the chemist carrying out the examination.

Preparation of Soil Suspension or Extract.—The determining of the method of preparing the soil suspension or extract for testing is a matter of considerable difficulty. These difficulties are discussed by Joseph and Martin (*Journal of Agricultural Science*, Vol. 13, p. 321), and for Sudan soil the proportions of soil to water was fixed at one to five, and the time allowed for extracting as one hour. In Sierra Leone we get results more easily by using one part soil to one part of water, and in this connection it must be remembered that the salt and the clay content are both much lower in Sierra Leone soils. In using the colorimetric method in Sierra Leone we take twenty grams soil, add twenty grams of water and shake—allow to stand for one hour and then centrifuge in a small hand centrifuge about 1,500 r.p.m. for five minutes. Almost invariably the supernatant liquid is quite clear. Ten cubic centimetres of this liquid is poured into a standard size glass tube, the indicator added and compared with standards.

8. Total Nitrogen.

The Committee agreed to adopt the Kjeldahl method, but recommended steam distillation as a method of overcoming difficulties of spraying.

Nitrogen.—In soil survey work which involves the sampling of various places on only one occasion, it is quite unnecessary to determine ammonia or nitrates, and total nitrogen is the only nitrogen determination which need be carried out.

9. Analysis of the Clay Fraction.

Here again, the Committee thought it advisable to tie the hands of the chemist. This analysis involves fusion of the clay with a fusion mixture and the subsequent estimation of silica, iron, alumina and "combined water." In so far as the estimation of silica,

iron and alumina is a purely chemical problem any of the accepted methods are probably satisfactory. The Committee thought that the combined water might be estimated as the "loss on ignition," less the organic matter present, the organic matter present being determined as in paragraph 6 above.

10. Soluble Salts.

The Committee thought that the methods described in the following paragraphs are suitable:—

Total Soluble Salts.—Here again the chief difficulty is to determine the proportions of soil and water and the length of time the extraction is to be allowed to last. Very convenient proportions are one part soil to five parts water, this being allowed to stand twenty-four hours, and it is suggested that this method of extraction be adopted.

Filtering.—In some cases there is a difficulty in securing a clear solution, this is not usually so with acid soils, but in cases where a clear filtrate cannot be obtained by ordinary filter paper, it can generally be obtained by filtering through a thin film of collodion. To prepare this take a Buchner funnel and stick a filter paper on to the floor of the filter by means of rubber solution applied round the edges of the filter paper. After this is dry run a solution of collodion on to the filter paper till the surface is covered (quickly pour off any excess), allow to dry slightly, and then wash with water. Fix into a filter pump, and it is ready for use. Do not let the collodion film get dry, or it will be ruined. Filter with the aid of an ordinary filter pump.

The whole filtrate or an aliquot part is then evaporated down to dryness, giving the amount of total salts, and the analysis of the dry salt thus obtained can be carried out in the ordinary way.

Electrical Resistance Method.—A quick way of determining the total salts is by means of the resistance of the solution to an electric current. A platinum cell consisting of two platinum plates covered with platinum black are used and the constant of the cell is determined by measuring the resistance of the cell when immersed in a solution of potassium chloride of known strength. The constant of the cell being known, the resistance of the soil solution is measured by dipping the cell into the soil solution and taking a reading. The specific resistance of the solution is the observed resistance cell constant. An approximation of the salts in the solution can then be obtained by calculation. A closer approximation can be obtained by plotting a curve showing the relation between the concentration of soil salt and the resistance, and referring resistances of soil solutions to this curve, corrections being made for temperature.

By the electrical method fifty determinations can be made in an hour, and if not strictly accurate, they are at least comparable.

11. Summary.

In general, the Committee held that some standardisation of sampling, classification and analysis was necessary in order to ensure that the essential minimum of trustworthy data for characterisation and comparison of soil was rendered available. The Committee have indicated in paragraph 2 what determinations, in their opinion, constitute this essential minimum and for the benefit of the agricultural chemist in the various Colonies they have described suitable methods by which this data may be obtained. The Committee was of the opinion that, subject to the necessity for producing results on a comparable basis, the chemist should be given as free a hand as possible.

Appendix.

INSTRUCTIONS FOR SOIL SAMPLING.

Soil sampling should be carried out by the trench, as no special implements are required and the same method therefore can be adopted all over the Colony and Protectorate.

Selection of Site for Sampling.—The areas sampled should be typical of the district, or if two or three types of soil exist in the same district each should be sampled. Single samples are not very much good, as qualities of the soil, not obvious to the eye, may vary, and opinions based on single samples be very misleading.

It will be left to the discretion of the officer in charge of the district as to which sites he thinks would give the most valuable information. Of course, a comprehensive survey like the above may take two or three years to complete, depending on the opportunities the officer has for visiting the various parts of his Province, but a start should be made at once.

Taking the Sample.—A hole or trench should be dug to the depth of four feet; generally about four by two is a suitable size. When the hole has been dug the side should be freshly scraped before taking the sample; a spade or basket should then be held pressed against the trench exactly one foot from the surface of the hole and a slice of earth of even thickness scraped from the side of the trench and caught in the basket; care should be taken that this should be an even slice from the top of the hole down to the bottom of the first foot. The soil so taken should be broken down into small lumps, thoroughly mixed and a sample about $1\frac{1}{2}$ lb. placed in the sample bags provided. The bag should be clearly marked in indelible pencil or ink on top with the place, the number of the hole and then the depth from which the sample is taken, *e.g.*—

$$\frac{\text{N'jala}}{\frac{3}{2}}$$

would mean that the sample was taken in a district near N'jala, it was the third hole dug and the sample was from the second foot.

All four feet should be sampled as described above.

Samples may be sent in as taken. It is not necessary to sample a whole Province before sending in the samples from the first few holes.

Information to be sent with samples:—

1. The position of each hole should be indicated as clearly as possible, *i.e.*, chiefdom, district, miles from nearest town or village.

2. Type of country, *e.g.*, forest, grassland, arable, etc.

3. Crops or trees growing on land, especially noting any dominant weeds.

4. General information, such as stony or clay soil, drains easily or badly, good or bad crops growing.

5. Topographical—hilly, undulating, flat, marshy, etc.

PAPER No. XXVI.

METEOROLOGICAL RECORDS OF THE GOLD COAST FOR 1927.

COMPILED BY N. P. CHAMNEY AND J. M. ADAMS.

During the year under consideration there have been a large number of requests sent to the Department for information as to data other than rainfall, and it has been considered, therefore, that the scope of this paper should be enlarged to cover all records taken at the stations.

The Bulletin No. 2 of the Department on the Rainfall of the Gold Coast has been in great demand both locally and in other countries, and it is proposed to revise this shortly to include all meteorological data, and thereby widen the scope of its utility.

Stations.

There are no stations of the first or second orders established at present in the Gold Coast, but there are fourteen of the class known as Auxiliary Climatological Stations which rank as third order stations of the International Classification.

Of these two only, Kumasi and Accra are fitted with barometers, but Accra has, in addition, barograph, thermograph, anemometer and a Campbell Stokes sunshine recorder.

Observations are taken daily at all these stations at 9 o'clock G.M.T.

In addition, there are 53 stations where rainfall records only are taken.

Kpedsu, where records have been kept up to 1926, was closed down during the year.

New stations opened this year are: Bole, Kpeve and Akropong.

Records were recommenced at Gambaga and Goaso.

Rainfall Tables.

The monthly rainfall at each station during 1927 are given in Table II, and in addition the highest and lowest rainfalls recorded in previous years for each station.

Unusual figures have been recorded at Essuasu, 102·63 in. in 105 days, and the monthly figures at Half Assini 23·44 in. in

17 days, Axim 22·61 in. in 27 days, Atuabo 20·02 in. in 14 days, all in June, and Mpraeso 20·02 in. in 20 days, and Juaso 21·71 in. in 22 days, both in October, are worthy of note. On the whole, it may be stated that the rainfall was less than that of 1926, but the extremes at each end of the tables approach more nearly.

A notable fact is that the highest rainfall on any one day, 4·78 ins., was recorded at Accra on May 13th.

In the Rainfall Map for 1927 have been included not only the stations where records are now being kept, but also records from stations where records have ceased to be taken and also some of those from the old German stations in Togoland. It must be understood that these maps are based on the average rainfall of each station up to and including the year named. It is interesting to note that with inclusion of stations around the range of hills stretching from Mampong to Aburi, the coincidence of rainfall to the physiography of the country becomes more marked.

Degrees of Wetness.

These figures are given in Table I, and show in one, the total rainfall and the distribution of the precipitation.

They are obtained by the formula:

$$\frac{R \times D}{100}$$

where R = total rainfall and D the wet days.

This gives a more accurate idea of the prevailing moisture conditions in relation to agriculture than does the mere statement of total rainfall.

Temperatures.

The average monthly figures for the maximum and minimum temperatures in the shade, together with other data, are set out in Table III.

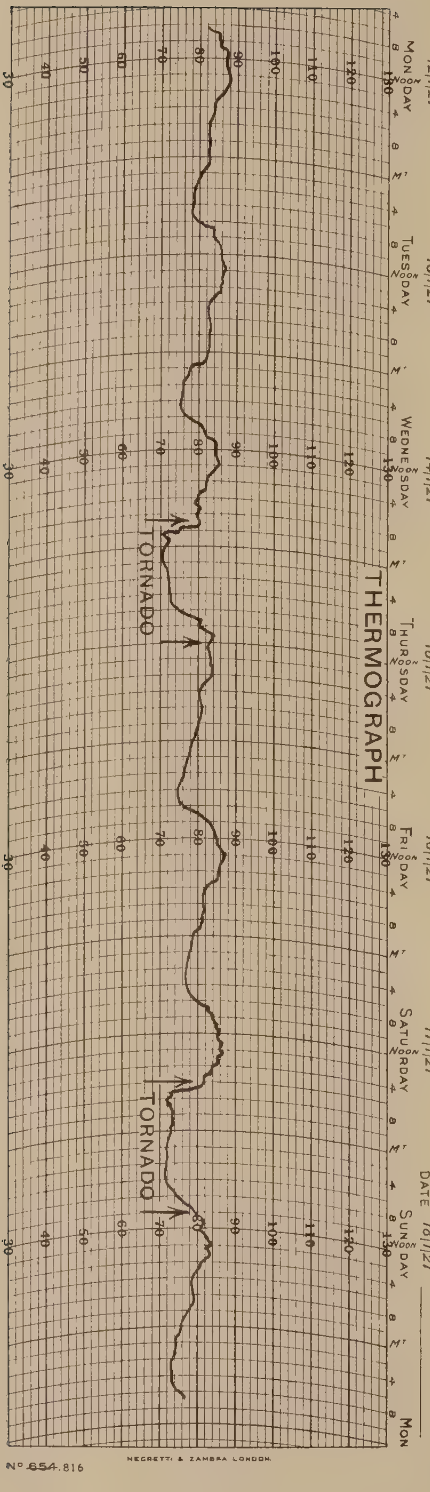
On reference to this Table, it will be seen that the greatest range of temperature is experienced at Akuse, closely followed by Kintampo and Tamale, while Aburi registers little difference between maximum and minimum.

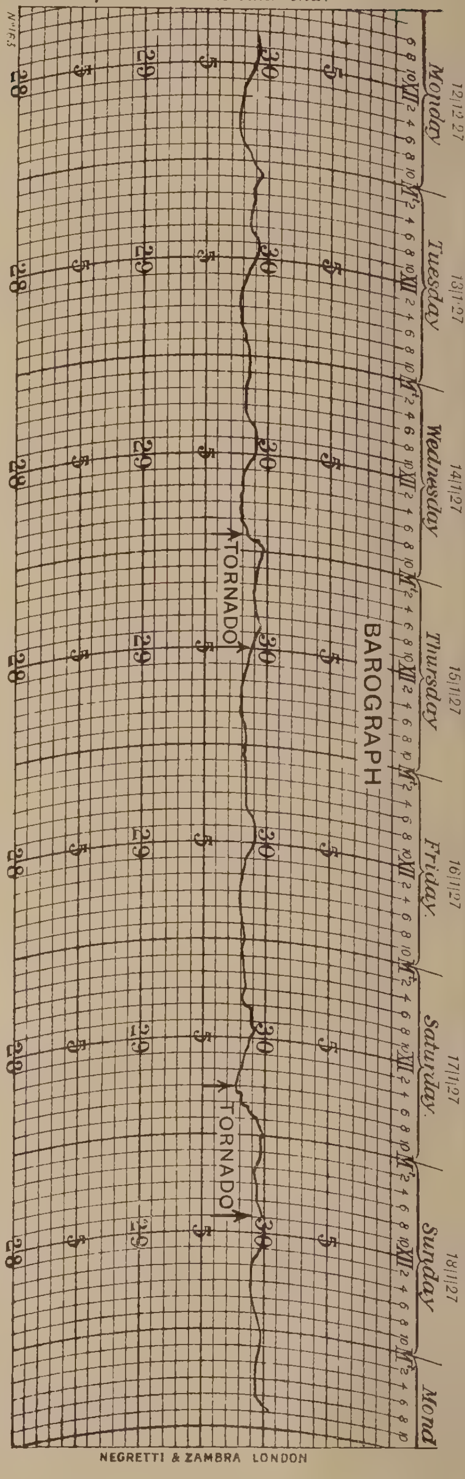
The highest temperature recorded during the year was 115° at Kintampo in June 25th, but in nine months out of the twelve, Tamale recorded the highest figures, which ranged between 99° and 109°.

The lowest temperature in the shade was 49° at Kumasi, on January 12th, but Kintampo had the lowest figures for nine months of the year, with figures of 50°-51°.

PLATE XXIV.

To put under the other end.





The range of shade temperatures gives an idea of the relative heat of the district concerned, and it is found that the coastal belt, as recorded at Accra, Achimota, Axim, Sekondi, and Keta, shows small range of temperature, due to the cooling sea-breezes, and the maximum ranges are found in the open savannah of the North and Togoland, as recorded by Kintampo, Tamale and Akuse.

The maximum Solar radiation occurs always at Tamale, and has reached, this year, a figure of 175° on two occasions.

Relative Humidity.

This figure, obtained by calculation from the difference of the readings of the Hygrometers (wet and dry bulb), is found to be highest in the forest area and lowest in the open country.

Asuansi, Aburi, Tarkwa, Begoro are all of the order of 80 per cent. or over, while the northern stations rarely exceed 70 per cent.

During the Harmattan the relative humidity drops very quickly; an actual record of a drop of 65 per cent. (from 85 per cent. to 20 per cent.) in two days having been noted in January at Accra. A corresponding rise occurs at the finish of the Harmattan.

Isotherms.

An Isothermic map has been prepared, but space does not allow of its inclusion in the present paper. It suffices to say that the Isotherms follow the general configuration of the country, and have their axes in the South-West corner of the Colony. They rise steeply on the far side of the arc of mountains running from Kumasi to Aburi, and reach the maximum at the Tamale-Akuse line, whence a slow fall occurs towards the French frontier of Togoland.

Barometer Readings.

Barometers are only employed at Accra and Kumasi, and are therefore of local interest only. A barograph is installed at Accra and a specimen chart of one week's readings is found on Plate XXIV, fig 1. A Thermograph chart for the same period is found on Plate XXIV, fig. 2, as showing the influence of the storms recorded on January 14th and January 17th. It will be noted that as the storm approached, a rise in the barometer was coincident with a sharp fall in temperature. The reverse process is noted on the departure of the storm area. The barograph shows slightly the depression which takes place in pressure as the centre of the storm approaches.

It is evident that in neither case, however, did the exact centre of the storm pass overhead or the depression would most certainly have been more marked. It serves, however, to show the value of the instruments in the study of storms and climatology generally.

Phenology.

The science of phenology or the relation of weather to crops is in its infancy on the Gold Coast, but a start has been made on the correlation of cacao yields and rainfall in Paper 12 of this Year-book.

It is hoped, during 1928, to make further studies of these correlations, which undoubtedly are important as a factor in forecasting the yields of crops. In the Paper mentioned above, the rainfall during April has an evident relation to the following crop of cacao, and it is fairly certain that other factors may be found to influence the yields of other crops.

A severe Harmattan will check plants to cause such loss of leaf that the season's crop may be seriously diminished.

Lack of rain or unsuitable distribution causes dropping of flowers and consequent loss of crop, while excessive rain or prolonged distribution affects the sun drying of cacao or coffee and results in a loss of quality.

Lack of knowledge of the meteorology of a district may therefore well cause failure of an attempt to establish an agricultural industry, and for that reason alone is of importance to any one connected with agriculture in any of its branches.

TABLE I.
Degrees of Wetness 1927.

Kibi	119
Abompasu, Axim	116
Esuasu	108
Adeja	101
Hemang	100
Tarkwa	97
Juaso	94
Agona	93
Half Assini	92
Wiawso	91
Atwabo, Goaso	83
Begoro, Siwum	78
Dunkwa, Mpraeso, Mpirim	77
Kintampo, Kumasi	75
Tafo	70
Oda, Effiduase, Anyinam	69
Seysie (Butre), Asromaso	67
Asamankese, Koforidua	63
Aburi, Salaga	59
Kpeve	58
Kodia Kese, Ejisu	57
Asuansi	53
Tikrom	50
Wenchi	49
Nkawkaw	48
Bole	47
Bekwai, Mpenassa, Angu	45
Ejura, Mampong	44
Sekondi	43
Sunyani, Yendi, Kete Kratchi	42
Peki Blengo, Wa	41
Ajua	39
Gambaga	38
Mansu, Tamale	35
Odumase, Nsawam	33
Zuarungu	31
Akuse	29
Asuminya	25
Akropong	20
Abra	16
Accra	15
Keta, Achimota	11
Labadi	8
Saltpond	7

TABLE II.

Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1927.

MONTH.	1 Essuasu (2 years).	2 Half-Assini (6 years).	3 Atuabo (1 year).	4 Agona (2 years).	5 Juaso (12 years).	6 Axim (13 years).	7 Hemang. (10 years).	8 Wiawso (12 years).	9 Adeja (1 year).	10 Mpraeso (10 years).	11 Abompasu (6 years).	12 Nkawkaw (2 years).	13 Asromaso (2 years).	14 Anyinam (21 years).	15 Kibi (15 years).	16 Mpirim (2 years).
January	2·73	0·89	0·83	0·21	0·60	0·80	0·15	0·42	0·84	1·12	0·25	1·00	Nil	0·92	1·75	0·20
February	2·25	1·86	0·68	1·27	0·62	4·32	3·88	1·49	1·76	0·56	3·45	1·05	0·75	1·31	3·13	3·20
March	10·12	7·58	3·22	4·96	7·33	6·73	13·77	4·63	6·58	2·56	3·22	2·80	3·44	5·12	9·35	5·78
April	7·56	7·22	9·83	9·49	6·16	1·77	9·67	12·35	10·91	5·66	8·10	5·20	5·87	4·70	6·97	9·13
May	10·55	12·53	10·59	7·38	6·51	12·48	12·15	9·49	9·56	5·78	5·58	5·31	5·52	10·99	7·34	11·19
June	12·71	23·44	20·02	11·72	11·11	22·61	7·50	11·59	4·51	6·56	7·79	9·45	7·29	8·49	9·28	8·84
July	2·17	4·25	3·13	4·80	2·51	1·87	2·87	6·54	4·06	8·52	5·12	5·50	4·18	3·72	3·45	3·30
August	Nil	0·30	0·05	3·89	1·18	0·42	1·29	0·39	1·32	2·22	2·15	2·00	1·95	3·03	0·93	0·99
September	13·72	5·10	2·80	13·88	12·51	0·73	4·27	8·53	12·23	13·73	12·87	14·85	8·22	9·36	9·93	10·67
October	18·80	3·09	11·26	12·02	21·71	7·37	10·13	11·50	15·05	20·02	13·65	15·40	15·47	14·77	6·02	10·36
November	18·50	10·02	6·32	5·14	4·38	8·04	5·36	4·78	2·45	2·99	4·90	3·95	2·31	3·44	3·50	0·76
December	3·52	5·67	10·29	1·89	1·20	6·87	2·89	1·43	1·38	0·87	3·11	2·00	0·36	1·75	5·73	2·40
TOTAL ..	102·63	81·95	79·02	77·10	76·12	74·01	73·93	73·14	70·65	70·59	70·19	68·51	68·36	67·60	67·38	66·82
Number of Rainy Days (·01 inch or more) ..	105	112	105	121	123	157	136	125	143	109	166	70	98	102	176	115
Highest previous Rainfall	—	88·77	—	—	75·19	109·65	85·86	70·44	—	85·26	67·39	—	—	95·07	79·90	67·14
Lowest previous Rainfall	73·38	61·63	—	67·15	53·42	47·64	47·04	40·14	—	57·55	65·18	60·68	23·23	40·27	45·77	—

TABLE II.—*continued*

Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1927.

MONTH.	17 Effiduase (2 years).	18 Dunkwa (13 years).	19 Siwum (Dadiasu) (6 years).	20 Tarkwa (24 years).	21 Tafo (2 years).	22 Kodia-Kese (2 years).	23 Salaga (13 years).	24 Begoro (6 years).	25 Kumasi (21 years).	26 Goaso (4 years).	27 Asamankese (5 years).	28 Kintampo. (13 years).	29 Ejisu. (2 years).	30 Oda (13 years).	31 Tikrom (2 years).	32 Nsawam (2 years).
January	0·05	0·59	1·50	2·67	0·61	0·50	0·34	0·53	0·23	0·44	1·52	Nil	1·23	0·81	0·48	2·59
February	1·51	1·02	0·97	2·35	2·43	4·35	0·51	5·12	1·17	1·62	1·98	2·20	1·09	1·79	1·24	1·81
March	3·60	2·97	2·62	7·34	5·42	4·44	0·14	5·57	6·27	2·51	7·67	1·07	5·64	5·76	4·17	3·97
April	6·60	7·78	8·92	5·09	4·38	6·99	6·55	7·92	9·93	6·10	5·63	6·01	10·23	4·33	8·29	3·42
May	6·29	8·91	7·20	8·74	6·28	4·23	7·08	8·11	3·69	9·20	6·43	11·81	5·13	6·39	5·80	10·89
June	7·98	8·54	12·36	10·91	12·32	5·45	8·48	6·64	4·95	5·63	5·13	11·25	6·20	4·62	5·50	5·13
July	6·00	4·18	5·28	1·49	5·01	6·49	6·07	3·61	3·70	2·56	6·44	6·46	4·78	1·92	4·92	2·95
August	1·17	0·80	1·17	0·09	1·11	0·83	5·61	1·18	0·38	3·52	1·11	1·67	0·85	1·31	1·06	Nil
September	16·31	6·16	8·03	3·94	6·50	12·54	14·33	5·75	11·59	8·62	4·28	8·82	9·08	5·51	7·00	3·58
October	13·89	14·15	14·73	11·34	10·98	12·56	9·59	10·81	15·51	13·67	6·60	8·15	11·94	7·88	14·49	7·91
November	0·67	4·70	2·49	6·17	4·51	2·96	1·88	1·77	2·23	4·59	4·37	1·12	0·37	7·12	0·48	4·45
December	2·09	6·18	0·63	3·43	3·28	0·20	Nil	3·29	0·57	1·04	7·61	Nil	0·26	8·63	2·05	8·70
TOTAL ..	66·16	65·90	65·90	63·56	62·83	61·53	60·58	60·30	60·22	59·50	58·77	58·56	56·90	55·97	55·48	55·40
Number of Rainy Days (·01 inch or more) ..	105	117	118	153	111	93	98	129	124	139	108	128	100	123	91	59
Highest previous Rainfall	—	77·91	73·62	95·03	—	85·83	64·52	72·86	70·40	50·79	77·47	100·58	64·45	83·75	59·37	—
Lowest previous Rainfall	24·03	45·55	70·61	48·22	61·39	—	37·79	50·43	40·07	44·94	51·43	48·87	—	43·61	—	49·01

TABLE II—*continued.*

Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1927.

MONTH.	33 Koforidua (6 years).	34 Mpenassa (3 years).	35 Wa (11 years).	36 Bole (10 months).	37 Wenchi (6 years).	38 Angu (2 years).	39 Ejura (12 years).	40 Mampong (Ash.) (2 years).	41 Seysie (7 years).	42 Kpeve (10 months).	43 Bekwai (14 years).	44 Peki Blengo. (13 years).	45 Sunyani (13 years).	46 Aburi (37 years).	47 Mansu (14 years).	48 Kete-Kratchi (9 years).
January	0·29	1·80	Nil	—	Nil	0·53	1·02	Nil	1·68	—	0·18	Nil	Nil	2·01	0·70	3·70
February	1·72	5·73	0·28	—	3·35	1·15	2·30	1·10	3·36	—	2·38	0·90	1·34	2·48	0·75	0·66
March	1·70	4·46	Nil	0·03	2·87	6·44	2·84	3·65	4·06	4·31	5·41	4·74	2·27	6·40	3·50	1·12
April	9·61	3·32	4·68	9·62	8·57	2·98	10·04	5·80	3·28	4·44	10·78	5·79	6·44	5·51	3·45	4·42
May	6·27	8·21	12·33	6·87	6·30	11·23	4·55	11·22	12·76	5·33	5·35	9·07	5·31	3·47	7·05	6·45
June	7·10	13·04	6·54	10·33	4·01	11·44	7·29	7·89	11·90	5·91	6·16	4·59	6·81	3·81	8·75	11·95
July	3·61	2·50	7·07	7·82	5·12	1·25	4·67	Nil	1·45	5·10	1·74	3·32	1·48	3·00	1·00	2·99
August	0·40	0·55	7·57	4·20	2·94	0·57	0·12	0·31	0·27	0·52	0·10	2·54	1·67	0·52	Nil	1·34
September	6·53	4·75	7·86	9·18	5·77	3·73	7·44	9·54	3·52	9·99	6·60	4·68	9·71	2·96	2·85	5·74
October..	7·31	5·47	7·80	5·97	11·44	7·26	9·47	10·02	5·48	9·56	6·72	7·30	11·95	5·55	9·05	5·11
November	2·97	2·70	0·60	0·60	3·03	2·41	1·57	1·57	2·28	2·11	2·83	3·23	0·85	4·08	4·40	1·10
December	7·62	2·46	Nil	Nil	Nil	3·96	0·40	1·61	1·72	2·53	1·26	2·48	0·50	8·02	5·40	1·50
TOTAL ..	55·13	54·99	54·73	54·62	53·40	52·95	52·71	52·51	51·76	49·80	49·51	48·64	48·33	47·81	46·90	46·08
Number of Rainy Days (·01 inch or more) ..	114	82	75	86	91	86	83	84	129	117	91	84	87	123	75	91
Highest previous Rainfall	53·97	60·27	50·71	—	60·95	—	80·75	59·96	58·96	—	104·90	68·46	69·47	73·16	83·70	60·41
Lowest previous Rainfall	51·78	58·96	29·08	—	58·25	49·58	47·45	—	58·30	—	46·21	36·33	41·30	32·09	54·46	43 61

TABLE II—*continued.*

Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1927.

MONTH.	49 Akuse (13 years).	50 Sekondi (24 years).	51 Yendi (6 years).	52 Zuarungu (10 years).	53 Gambaga (3 years).	54 Odumase (3 years).	55 Tamale (18 years).	56 Asuansi (19 years).	57 Ajua (8 years).	58 Keta (22 years).	59 Asuminya (6 months).	60 Akropong (10 months).	61 Achimota (3 years).	62 Abra (6 years).	63 Accra (41 years).	64 Labadi (5 years).	65 Saltpond (13 years).
January	0·68	0·56	0·43	Nil	Nil	0·08	Nil	0·08	0 41	0·04	—	—	0·45	Nil	0·50	Nil	Nil
February	2·68	4·54	0·95	Nil	0·10	2·33	1·50	3·40	2·61	5·63	—	—	5·10	4·93	3·87	3·81	0·45
March	4·11	2·63	0·27	Nil	0·15	3·89	Nil	3·18	1·68	1·77	—	2·05	1·54	2·14	1·88	2·42	2·55
April	5·70	5·09	3·37	2·02	0·68	6·40	6·58	6·86	3·38	6·07	—	2·73	2·19	2·64	1·40	0·56	3·82
May	3·35	7·73	5·72	4·32	3·95	2·96	3·04	2·95	7·93	6·55	—	4·09	2·98	3·99	6·60	5·71	4·43
June	6·65	11·81	8·12	8·46	6·03	4·12	10·18	5·28	8·09	8·80	—	4·96	2·68	3·89	2·10	1·62	1·75
July	3·27	1·88	4·90	8·09	8·55	2·99	2·62	0·91	1·52	Nil	5·87	1·03	Nil	0·26	0·39	0·78	Nil
August	Nil	Nil	3·68	6·54	5·30	Nil	7·42	2·22	0·27	0·42	1·98	Nil	Nil	Nil	0·04	Nil	Nil
September	5·15	3·46	8·52	9·11	11·40	4·40	5·44	2·07	2·89	0·06	10·54	4·24	Nil	0·55	0·13	0·05	0·35
October	8·90	2·12	6·39	4·12	3·98	9·23	4·81	4·59	3·95	1·96	12·61	5·77	2·84	2·16	1·48	2·22	0·40
November	2·00	2·28	1·57	0·92	0·73	2·09	0·18	7·72	2·43	2·69	3·46	Nil	5·83	2·15	1·16	1·37	2·79
December	2·97	3·03	Nil	Nil	Nil	3·91	Nil	1·96	2·81	2·45	0·42	4·14	4·93	2·49	5·29	5·68	3·59
TOTAL ..	45·46	45·13	43·92	43·58	42·87	42·40	41·77	39·22	37·97	36·44	34·88	29·01	28·54	25·20	24·84	24·22	19·73
Number of Rainy Days (·01 inch or more) ..	64	97	96	71	88	78	85	136	104	31	73	68	41	65	60	35	36
Highest previous Rainfall	58·98	57·76	67·12	51·62	56·47	49·77	61·77	74·17	49·03	51·44	—	—	24·09	34·18	44·20	36·87	43·80
Lowest previous Rainfall	35·14	32·98	46·12	37·93	34·75	43·43	32·36	35·62	36·81	13·88	—	—	21·00	27·28	10·84	10·78	24·38

TABLE III.

Temperature Records for the Year ending 31st December, 1927.

MONTH.	KETA.			TAMALE.			TARKWA.			SEKONDI.			ACCRA.			KUMASI.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
January	85·5	75·4	80·4	96·6	59·0	77·8	88·7	66·3	77·5	87·8	70·5	79·1	87·1	72·4	79·7	88·7	60·5	74·6
February ..	90·6	77·0	83·8	100·5	67·4	83·9	93·1	71·7	82·4	88·2	74·9	81·5	86·7	75·7	81·2	91·9	69·3	80·6
March	84·0	75·2	79·6	103·7	71·8	87·7	93·0	71·5	82·2	88·0	75·7	81·8	87·3	76·2	81·7	90·8	71·9	81·3
April	83·4	73·8	78·6	96·6	70·9	83·7	92·0	71·5	81·7	87·5	75·1	81·3	86·6	75·3	80·9	88·7	70·8	79·7
May	87·0	80·7	83·8	94·1	69·7	81·9	92·1	71·8	81·9	87·8	75·2	81·5	85·6	75·7	80·6	88·6	70·3	79·4
June	86·3	81·3	83·8	88·8	68·1	78·4	88·4	67·8	78·1	83·6	73·2	78·4	84·3	74·1	79·2	85·6	70·8	78·2
July	86·9	77·5	82·2	87·1	68·0	77·6	89·5	69·6	79·5	81·9	71·5	76·7	80·3	73·1	76·7	82·3	69·7	76·0
August ..	82·1	75·3	78·7	86·5	67·4	76·9	84·9	68·2	76·5	80·6	70·6	75·6	78·6	70·9	74·7	81·3	68·6	74·9
September ..	84·7	74·9	79·8	88·1	66·8	77·4	85·2	70·7	77·9	81·4	72·4	76·9	80·0	73·4	76·7	82·5	70·1	76·3
October ..	85·5	77·1	81·3	91·3	67·1	79·2	89·5	71·2	80·3	85·2	72·5	78·8	85·0	74·5	79·7	86·8	70·0	78·4
November ..	83·5	75·7	79·6	96·9	63·0	80·1	91·2	70·2	80·7	88·5	73·3	80·9	87·0	75·3	81·1	91·1	71·0	81·0
December ..	85·8	76·1	80·9	98·6	59·8	79·3	80·7	71·6	76·1	88·6	75·3	81·9	87·0	75·7	81·3	90·8	70·4	80·6
Mean	85·6	76·6	81·0	94·0	66·6	80·3	89·1	70·2	79·6	85·7	73·3	79·5	84·6	74·3	79·4	87·4	69·3	78·3

TABLE III—*continued.*

Temperature Records for the Year ending 31st December, 1927.

Month.	Asuansi.			Aburi.			Kintampo.			Axim.			Akuse.			Begoro.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
January ..	87·5	68·0	77·7	87·7	70·1	78·9	94·1	64·0	79·0	84·8	68·8	76·8	94·2	60·6	77·4	94·1	66·7	75·4
February ..	89·5	70·9	79·7	89·0	71·3	80·1	98·4	64·9	81·6	86·2	73·9	80·0	96·3	65·5	80·9	94·0	63·3	78·6
March	89·0	71·2	80·1	89·2	71·8	80·5	98·1	63·8	80·9	86·4	72·6	79·5	96·6	65·7	81·1	93·9	65·1	79·5
April	88·4	72·1	80·2	88·1	70·9	79·5	92·0	64·1	78·0	86·1	70·9	78·5	94·5	65·7	80·1	91·6	64·3	77·9
May	87·9	71·7	79·8	88·4	71·7	80·0	91·1	64·1	77·6	85·9	72·1	79·0	95·7	64·4	80·0	89·2	65·4	77·3
June	83 6	70·5	77·0	84·9	69·4	77·1	86·9	63·2	75·0	82·1	70·9	76·5	92·3	61·6	76·9	86·4	65·8	76·1
July	82·5	70·5	76·5	81·6	67·9	74·7	84·5	66·6	75·5	79·5	71·3	76·2	88·5	59·9	74·2	85·0	65·3	75·1
August ..	81·3	68·9	75·1	81·6	66·6	74·1	84·9	65·2	75·0	80·2	70·3	74·9	90·9	59·2	75·0	81·1	66·1	73·6
September ..	81·8	71·3	76·5	82·0	68·2	75·1	85·8	68·9	77·3	82·2	71·0	75·6	89·9	59·8	74·8	81·7	67·9	74·8
October ..	84·8	71·2	78·0	84·1	70·0	77·0	87·6	66·7	77·1	84·6	71·7	76·9	91·9	60·8	76·3	84·4	67·9	76·1
November ..	85·4	69·9	77·6	85·0	70·8	77·9	91·7	66·0	78·8	81·2	71·3	77·9	93·9	60·4	77·1	87·7	68·4	77·8
December ..	86·3	70·8	78·5	85·4	71·7	78·5	93·6	62·8	78·2	85·6	72·9	79·2	86·9	60·0	77·4	87·2	67·9	77·5
Mean	85·6	70·6	78·1	85·6	70·0	77·8	90·4	65·0	77·8	83·7	71·4	77·6	92·6	61·9	77·2	87·2	66·2	76·6

TABLE III—*continued*

Relative Humidity, 1927.

Month.	Asuansi.	Axim.	Aburi.	Tarkwa.	Begoro.	Kumasi.	Sekondi.	Accra.	Akuse.	Keta.	Kintampo	Tamale.
January	83·3	86·5	66·3	86·2	79·7	78·5	77·8	66·0	67·2	73·5	51·0	66·8
February ..	86·0	86·1	84·9	85·9	80·8	80·3	81·9	76·5	67·8	72·6	59·3	68·9
March	86·5	81·7	82·0	83·5	83·8	82·5	79·7	73·5	65·9	72·2	66·7	50·7
April	86·8	85·5	85·1	86·1	82·9	84·8	81·0	75·0	74·3	72·3	72·2	63·0
May	87·0	84·9	85·0	81·0	84·9	83·8	80·7	68·4	74·1	72·2	73·0	67·0
June	87·7	89·7	84·3	85·7	87·5	87·7	84·5	77·6	78·8	71·0	78·4	76·7
July	91·5	85·8	89·7	84·5	88·6	84·4	82·9	80·6	74·9	66·2	75·5	77·9
August	91·9	87·9	88·5	84·2	90·6	85·8	84·7	78·2	64·2	79·3	76·5	76·8
September ..	92·4	89·7	91·3	89·2	91·4	88·2	86·2	78·7	68·3	63·8	81·1	79·6
October	88·2	89·9	88·1	86·1	85·4	86·3	83·7	71·1	73·9	70·1	75·4	73·5
November ..	88·0	83·6	90·3	85·9	81·9	83·0	79·7	73·3	72·4	73·0	67·8	56·3
December ..	89·5	87·4	91·0	88·5	80·7	86·5	81·1	79·4	77·2	62·7	71·8	42·4
Mean	88·2	86·6	85·5	85·5	84·8	84·3	81·9	74·9	71·5	70·7	70·5	66·5

BULLETIN No. 14.

Department of Agriculture,
Gold Coast.

Yields of Funtumia Rubber on Experiment Stations 1906-1928.

BY

G. H. EADY,
Superintendent of Agriculture

Accra, August, 1928.

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1928.

Yields of Funtumia Rubber on Experiment Stations, 1906—1928.

Funtumia Elastica (Stapf.) is an indigenous forest tree found throughout the rain-forest of the Gold Coast and Ashanti, together with *Funtumia Africana* (Stapf.), with which it may easily be confused, the morphological characters of both species being nearly identical. The former species yields a high grade rubber equal to the best Para, whereas the rubber obtained from *Funtumia Africana* is valueless commercially.

The botanical difference between the two species is given below, together with a drawing describing the flowers and portion of leaf of each species.

FUNTUMIA.

Flower-buds cylindric, 7–9 lin. long; corolla-lobes linear, distinctly longer than the tube; corolla-tube constricted just below the middle; disc shorter than the ovary. (*Africana.*)

Flower-buds conical, 3–6 lin. long; corolla-lobes oblong, shorter than the tube; corolla-tube constricted near the base; disc exceeding the ovary. (*Elastica.*)

Funtumia Africana (Stapf.). Tree 15–80 ft. high, bark grey, smooth; branchlets foveolate in the leaf axils. Calyx $1\frac{3}{4}$ lin. long. Corolla subcylindric and 7–9 lin. long in bud; tube constricted just below the middle; lobes linear, 5–6 lin. long; disc 5-lobed or 5-partite, shorter than the ovary. Follicles spindle-shaped, acutely acuminate, semiterete, sides slightly keeled. Absence of pits in the nerve axils on the under surface of the leaves.

Funtumia Elastica (Stapf.). Tree up to 100 ft. high, bark pale, spotted; branchlets foveolate in the leaf axils. Calyx $2–2\frac{1}{4}$ lin. long. Corolla conical, up to 6 lin. long in bud; tube constricted above the base; lobes oblong, obtuse, $2\frac{1}{2}–3$ lin. long; disc 5-partite, slightly exceeding the ovary. Follicles oblong-clavate when closed, obtuse or rotundate at the apex, woody, obscurely keeled along the sides. Presence of minute pits in the nerve axils on the under surface of the leaves.

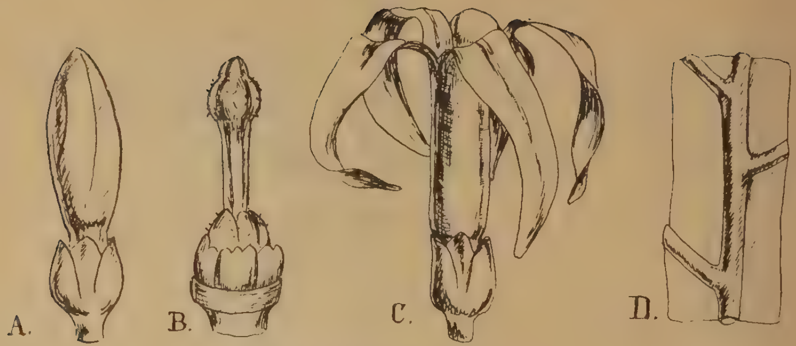


FIG. 1.—Funtumia africana.

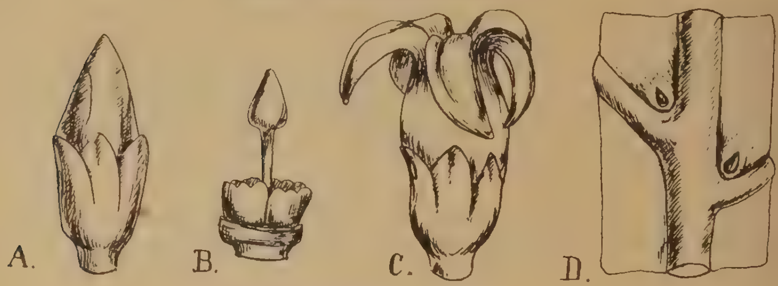


FIG. 2.—Funtumia elastica.

A = flower-bud.
B = gynæcium, showing disc.
C = open flower.
D = portion of under surface of leaf showing axils of veins.

In addition to its natural habitat, small plantations of *Funtumia elastica* have been planted in, or in the vicinity of, many towns and villages and in cacao farms, where it is used as a shade tree.

Before the yield of rubber it was possible to obtain from the tree was known, several European plantation companies and European planters had planted up extensive areas, chiefly in the Western Province, the intention being to work these in the same manner as Para plantations in other countries. One plantation, consisting of 22,000 trees, was planted as early as 1906, and was still in existence in 1913. Three other plantations, all in the Western Province, had been planted before 1911, with 37,000, 50,000 and 438,000 trees respectively, whilst one European Limited Company in the Eastern Province reported they had 150 acres in 1911.

At this date it was considered it would be possible and even profitable, to cultivate the tree on plantation principles, this belief being shared by the Department of Agriculture, which at that period had conducted no extensive tapping experiments.

Previous to the introduction and cultivation of cacao and for many years subsequently, large numbers of forest trees were tapped by Africans and the latex converted into rubber, this product forming at that time a very important article of export.

With the advent of cacao, however, the industry was neglected with a corresponding decrease in production. In the Gold Coast at the present time very little rubber is produced, but the industry still exists in Ashanti where the trees are plentiful.

The first Agricultural and Botanical Station opened in the country was at Aburi in 1891, and among other rubber-producing plants *Funtumia elastica* was planted in plantation form about 1892. In 1902, 50 acres were planted, the plantation still being in existence. In 1908, 65 acres were planted at the Tarkwa Agricultural Station, and 30 acres at Kumasi during 1907, soon after the Station was opened. All the Agricultural Stations opened subsequently were planted with small areas of the tree, many of which still exist.

Tapping experiments have been conducted at Aburi and Tarkwa only, most of them on the former Station, which was for many years the headquarters of the Department.

Rate of Growth of Funtumia.

Compared with *Hevea brasiliensis* the rate of growth of *Funtumia elastica* is very slow. Para rubber trees nine years old on the Aburi Agricultural Station have an average girth of 36 ins., whilst trees of the latter species of the same age measure only 14 ins.

The following figures relate to 112 trees, of which annual measurements were recorded from 1910 to 1921 inclusive. No records are available for the years 1922–1927. Recent measurements of the same trees show an average increase of 6·48 ins. or ·92 ins. per annum. The trees are 26 years old.

Year.	*Average at 3 ft. from Base.* ins.	*Increase.*
1909	10·75	—
1910	13·00	2·25
1911	14·66	1·66
1912	15·91	1·25
1913	16·81	·90
1914	17·66	·85
1915	17·98	·32
1916	18·43	·45
1917	19·01	·58
1918	19·66	·65
1919	20·21	·55
1920	20·91	·70
1921	21·72	·81
1928	27·20	6·48

Tapping-Methods Compared.

The first recorded tapping experiment was at Aburi in 1906, when eight trees, six years old, yielded one half-ounce of dry rubber per tree at one tapping. No other particulars are available.

The second tapping experiment recorded was in 1910; on this occasion 75 trees being operated on. The trees were divided into five blocks of 15 trees each. The first four blocks were tapped up to a height of 6 ft., seven tappings being made at intervals of ten days. Block 4 was tapped once only, but the tapping was extended up to 15 ft. from the ground. The trees were nine years old.

BLOCK 1.

Herring-bone System.

Fifteen trees, average girth 18 ins., 3 ft. from base. Side-cuts were first made at intervals of 12 ins. on each side of a vertical cut, the subsequent cuts being $1\frac{1}{2}$ ins. apart. The total weight of dry rubber obtained from the seven tappings was 12·10 ozs., the average being ·80 ozs. per tree.

FIG. 1.
Section of trunk showing method described in Block 1.

BLOCK 2.

Vertical System.

Vertical parallel cuts made with a V tapping knife at $1\frac{1}{2}$ in. intervals. Average girth of trees 19 ins. Total weight of dry rubber obtained from seven tappings was 14·34 ozs., equal to ·97 ozs. per tree.

FIG. 2.

Section of trunk showing tapping method in Block 2.

BLOCK 3.

Half Herring-bone System.

Half of each tree was tapped. The first side-cuts were made at intervals of 9 ins., subsequent cuts 1 in. below previous cuts. Average girth was 18 ins., 3 ft. from base. Total weight of dry rubber obtained from seven tappings, 9·17 ozs., or ·61 ozs. per tree.

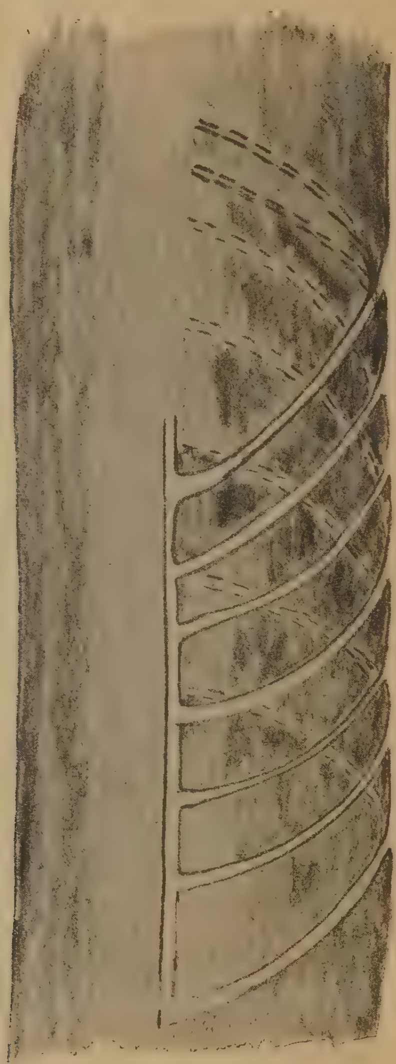


FIG. 3.

Section of trunk showing tapping method described in Block 3.

BLOCK 4.

Full Herring-bone System.

The whole of the circumference of the trees was tapped. The first tapping was made at intervals of 9 ins. on both sides of a vertical channel, subsequent tappings at 1 in. below previous tappings. The total yield of dry rubber obtained from seven tappings was 20·45 ozs., or 1·36 ozs. per tree.

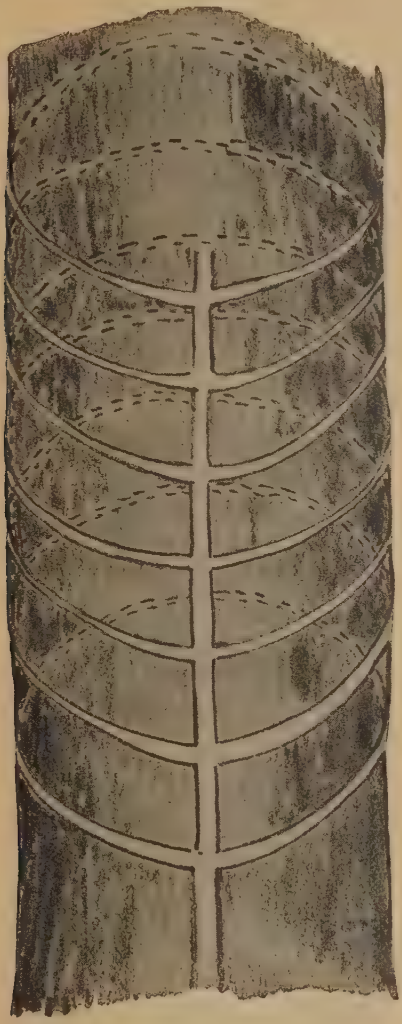


FIG. 4.

Section of trunk showing tapping method described in Block 4.

BLOCK 5.

Native System.

This experiment was designed with a view to comparing the native method of tapping with those used in the experiments described above. Fifteen trees were selected and tapped to a height of 15 ft. on the full herring-bone system, the Burgess knife and pricker being used. Average girth 18 ins. Yield of dry rubber per tree 1·34 ozs. The system described under Block 5 has given the best yields. The working expenses were considerably less, since as much rubber was obtained from one tapping as from seven tappings under the other systems.

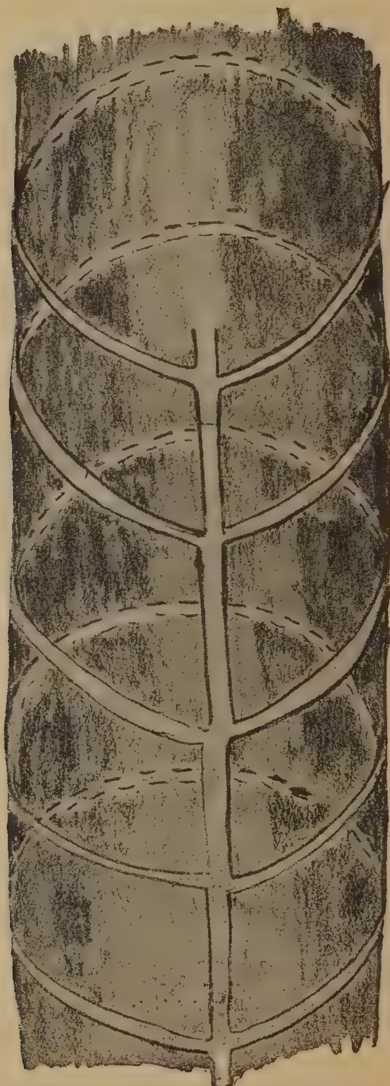


FIG. 5.
Full herring-bone method. Native system.

Relation of Yield to Girth.

In October, 1910, the experiment about to be described was commenced, 425 trees being operated on. The trees were divided into five groups containing trees of different girths. Lot (A) comprised trees from 10 to 12 ins., (B) from 12 to 14 ins., (C) 14 to 16 ins., (D) 16 to 18 ins., and (E) trees over 18 ins. Each group was again sub-divided into lots and tapped at different intervals. The tapping was carried out on the vertical parallel system to a height of 100 ins. from the base. Three incisions were made at each tapping, equal distances apart, and at subsequent tappings 2 ins. from previous incisions. The Christy tapping-knife and pricker

FIG. 6.
Method of tapping, showing vertical parallel method under experiment, "Relation of yield to girth."

was used throughout. Latex from each tree was measured and recorded separately and the rubber from each lot separately prepared.

The average girth of the trees at 3 ft. from the base before and after tapping, as well as the aggregate results, are given in the following table :—

Group.	*No. of Trees.*	*Average girth before experiment.*	*Average girth after experiment.*
A	78	11·18	11·53
B	100	13·25	13·81
C	104	15·01	15·56
D	80	16·88	17·45
E	63	19·12	19·56

TABLE I.—TRIALS OF FUNTUMIA RUBBER AT ABURI.

RELATION OF GIRTH OF TREES TO YIELD OF RUBBER OBTAINED.

Lot.	No. of Trees.	Girth of Tree.	October.		December.		February.		April.		June.		October.		Totals.	
		inches	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.	Latex c.c.	Dry Rubber grams.
A 1	20	10 to 12	525	248	—	—	—	—	—	—	465	200	208	81	1,198	529
A 2	20	10 to 12	—	—	526	252	—	—	—	—	—	—	—	—	526	252
A 3	20	10 to 12	—	—	—	—	311	207	—	—	—	—	—	—	311	207
A 4	18	10 to 12	—	—	—	—	—	—	330	130	—	—	—	—	330	130
B 1	32	12 to 14	1,052	525	723	247	366	174	—	—	799	145	—	—	2,940	1,091
B 2	33	12 to 14	1,147	485	—	—	780	300	—	—	709	289	—	—	2,636	1,074
B 3	35	12 to 14	922	485	—	—	—	—	784	238	—	—	450	170	2,156	893
C 1	33	14 to 16	1,228	538	871	371	548	395	—	—	—	—	—	—	2,647	1,304
C 2	35	14 to 16	1,254	635	—	—	804	442	—	—	671	290	—	—	2,729	1,367
C 3	36	14 to 16	1,363	650	—	—	—	—	1,136	305	—	—	478	282	2,977	1,237
D 1	26	16 to 18	1,072	329	745	324	384	206	391	98	—	—	—	—	2,592	957
D 2	27	16 to 18	758	430	—	—	568	293	—	—	513	231	214	94	2,053	1,048
D 3	27	16 to 18	1,095	630	—	—	—	—	879	293	—	—	372	202	2,346	1,125
E 1	21	Over 18	1,055	428	810	376	442	190	478	158	—	—	—	—	2,785	1,152
E 2	21	Over 18	918	462	—	—	538	264	—	—	552	278	324	174	2,332	1,154
E 3	21	Over 18	1,047	558	—	—	—	—	792	466	—	—	380	174	2,219	1,198

The total amount of rubber obtained in the whole experiment was 31 lbs. 15 ozs. This is equal to an average yield per tree of 1.31 ozs.

3A

The trees in the foregoing experiment were ten years old. The table of results indicates that the yield is higher in October to December than from February to April, and the results of a second tapping of Lot A in June shows that in this month the yield is good. The period over which good results are obtainable appears to be from June to December, or, when harmattan conditions are not severe, as late as January.

Varying the Tapping-Intervals.

The total yield per tree obtained in the trials above in three or four tappings at intervals of two, four and six months is given in the following table :—

TABLE 2.—TREES TAPPED AT INTERVALS OF TWO MONTHS—OCTOBER, DECEMBER AND FEBRUARY.

Block.	Average total yield per tree. (3 tappings in 6 months.)	
	Latex.	Dry Rubber.
B. 12 to 14 inches girth	66·69 c.c.	29·55 grams.
C. 14 " 16 " "	80·23 "	39·51 "
D. 16 " 18 " "	84·65 "	33·03 (a) "
E. Over 18 inches	109·85 "	47·33 (b) "

(a) Tapped again in April, making the total yield per tree 66·99 c.c. latex and 36·80 grams of rubber.

(b) Tapped again in April, making the total yield per tree 132·61 c.c. latex and 54·87 grams of rubber.

TABLE 3.—TREES TAPPED AT INTERVALS OF FOUR MONTHS.—OCTOBER, FEBRUARY AND JUNE.

Block.	Average total yield per tree. (3 tappings in 12 months.)	
	Latex.	Dry Rubber.
B. 12 to 14 inches girth	79·89 c.c.	32·54 grams.
C. 14 " 16 " "	77·87 "	39·05 "
D. 16 " 18 " "	68·11 "	35·33 (a) "
E. Over 18 inches	95·61 "	46·66 (b) "

(a) Tapped again in October, making the total yield per tree 76·03 c.c. latex and 38·81 grams dry rubber.

(b) Tapped again in October, making the total yield per tree to 111·04 c.c. latex and 57·04 grams rubber.

TABLE 4.—TREES TAPPED AT INTERVALS OF SIX MONTHS—OCTOBER, APRIL AND OCTOBER.

Block.	Average total yield per tree. (3 tappings in 18 months.)	
	Latex.	Dry Rubber.
B. 12 to 14 inches girth	61·80 c.c.	25·51 grams.
C. 14 „ 16 „ „	82·69 „	34·36 „
D. 16 „ 18 „ „	86·88 „	41·66 „
E. Over 18 inches	105·66 „	57·04 „

Grouped as above, the figures demonstrate that a two-months' interval between tappings has given almost as large a yield as four and six months' intervals.

The average yield per tree at the first and subsequent tappings at two months' intervals was :—

First tapping October	37·2	c.c. latex	17·7	grams	rubber
Second tapping December	28·1	„ „	11·7	„	„
Third tapping February	15·5	„ „	8·85	„	„

The 420 trees previously tapped in 1912 were retapped in 1913. The herring-bone system was adopted, two-thirds of the trees being tapped to a height of 100 inches from the base. The latex from each tree was measured in cubic centimetres, and the rubber from each block prepared separately. Coagulation was effected by adding a small percentage of Formalin to the latex.

The results in 1913 are shown in the following table :—

TABLE 5.

No. of trees.	Average girth.	Total yield latex.	Total yield dry rubber.	Average yield of dry rubber per tree.
	inches.	c.cs.	ozs.	ozs.
Block A. 56 ..	14·04	3,385	2 lbs. 17 ozs.	·644
Block B. 98 ..	16·45	5,247	4 lbs. 14 ozs.	·801
Block C. 104 ..	17·14	6,368	5 lbs. 12 ozs.	·889
Block D. 80 ..	18·57	5,504	5 lbs. 1 oz.	1·912
Block E. 62 ..	21·63	5,140	4 lbs. 11 ozs.	1·217

The total yield was 24 lbs. of dry rubber at one tapping, as against 32 lbs. obtained from the three and four previous tappings. The

trees had not healed well from the previous tapping a year ago, and retapping was not possible for several years.

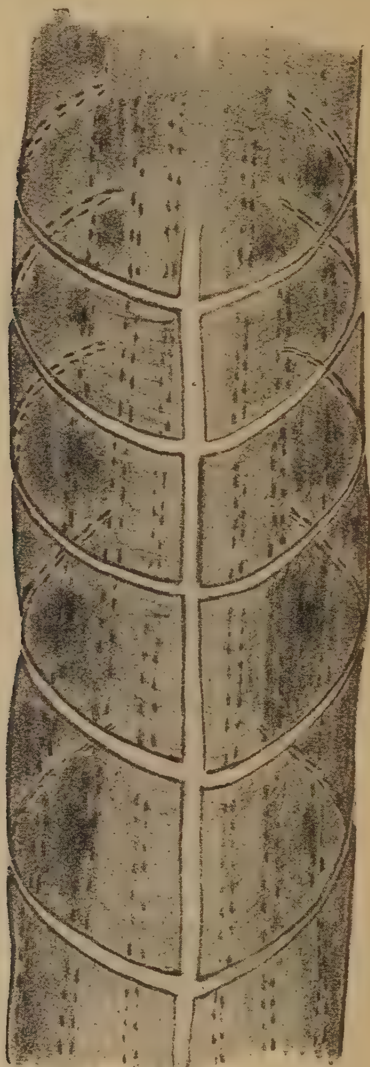


Fig. 7.

Section of trunk showing herring-bone system of tapping the 420 trees previously tapped as Fig. 6.

Comparison of Hevea with Funtumia.

A small experiment, designed to test the relative yield of Para and Funtumia, was conducted at Aburi in 1912, the object of the experiment being to produce as much rubber as possible with the minimum expenditure and with a relatively small number of tappings within a given period.

Ten Para and ten Funtumia trees were tapped during November on the herring-bone system, the tappings taking place on alternate mornings. Trees were tapped eleven times. Two-thirds of the circumference of each tree was operated on up to a height of six feet. Six side-cuts were made at each tapping twelve inches apart on the right and left sides alternately, subsequent cuts being two inches from previous incisions.

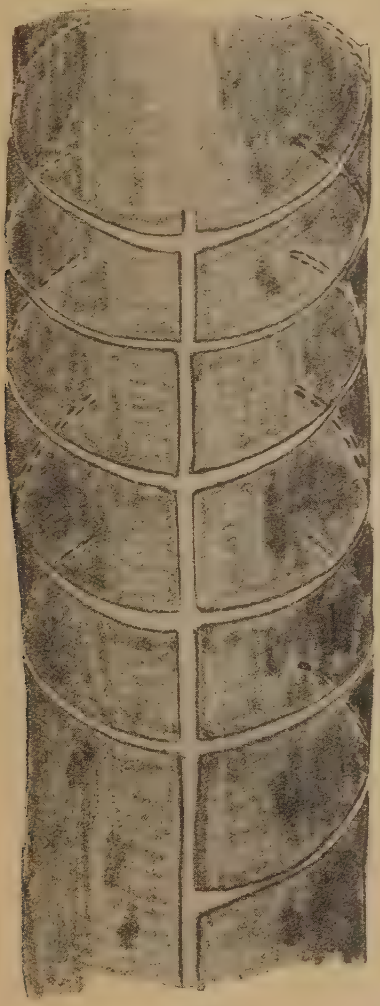


FIG. 8.

Method of tapping both species in the Para versus Funtumia experiment.

Total yields are shown in the following table :—

TABLE 6.

Para.			Funtumia.		
Date of tapping.	Yield of latex.	Yield of dry rubber.	Date of tapping.	Yield of latex.	Yield of dry rubber.
Nov.	C.C.	Grams.	Nov.	C.C.	Grams.
2	*	19	1	918	383
5	*	104	4	269	57
7	457	182	6	311	60
9	388	123	8	192	55
12	343	98	11	185	24
14	404	103	13	131	23
16	549	167	15	127	21
19	498	133	18	111	19
21	518	150	20	107	18
23	445	181	22	46	9
26	433	130	25	71	10

* Latex coagulated on the trees.

The average yield of dry rubber per tree was : Para 4·90 ozs. ; Funtumia 2·39 ozs. Average girth of the trees was 35·5 and 21·5 inches respectively. The trees were ten and eleven years old.

These yields from Funtumia are the best yet obtained from tapping of cultivated trees. It will be noticed that the Funtumia has given over 50 per cent. of its yield in the first tapping, whilst the yield from the first tapping of Para was small.

It is clearly seen from this Table that the rate at which Funtumia produces latex and rubber is far slower than is the case with Hevea (Para). If the rate of tapping, in the case of Funtumia, were slowed down so as just to keep pace, and no more, with the rate of production of latex by the tree, the amount obtainable at each tapping probably would not pay for the cost of the operation. It is necessary to over-tap, to the point of permanently injuring or even destroying the tree, before a profitable amount of latex is obtained. This procedure is justifiable only where the tree occurs naturally, and does not represent a definite amount of capital expended in establishment.

Miscellaneous Yield—Trials.

Trial I.—A small experiment with trees nine years old gave the following results. (*a*) Nine trees of 18 inches average girth tapped on the vertical parallel system in the month of January

gave 511 c.c. latex and 244 grams of dry rubber; tapped again in July the same trees yielded 327 c.c. latex and 92 grams of rubber; this is equal to 1·32 ozs. of dry rubber per tree. (*b*) Twenty-five trees of 15 inches average girth, tapped in March on the herring-bone system, with six consecutive tappings gave the yield stated below :—

Fig. 9.
Method of tapping described under Trial I. A.

Fig. 10.
Method of tapping described under Trial I.B.

	Date.					
Yield of grams ..	20th	24th	25th	28th	29th	30th
Dry Rubber ..	317	418	202	186	224	120

This is equal to 2·04 ozs. of dry rubber per tree.

This experiment was continued in 1912 on the same nine trees tapped the previous year. Tapping was done in July only. Average girth of the nine trees was 19·5 inches, and tapping was on the vertical parallel system. The yield of 715 c.c. latex and 321 grams of dry rubber is equivalent to 1·2 ozs. of dry rubber per tree.

TRIAL II.—On the Tarkwa Agricultural Station in 1915, 246 trees were tapped, the Christy knife and pricker being used. Particulars are given below :—

TABLE 7.

No. of trees.	Age of trees.	Average girth.	Total yield latex c.c.	Total yield dry rubber.
246	8 years	14 inches	39,797	30 lbs.

The average yield of dry rubber per tree was 1·9 ozs. Formalin was used as a coagulant.

The following experiment was carried out at Tarkwa during 1915–1918 on 979 trees having an average girth of 22·58 inches when the experiment commenced. Tapping was on the herring-bone system (Fig. 7) to a height of 100 inches, the side-cuts being 6 inches apart on two-thirds of the circumference.

Result of the experiment is given below :—

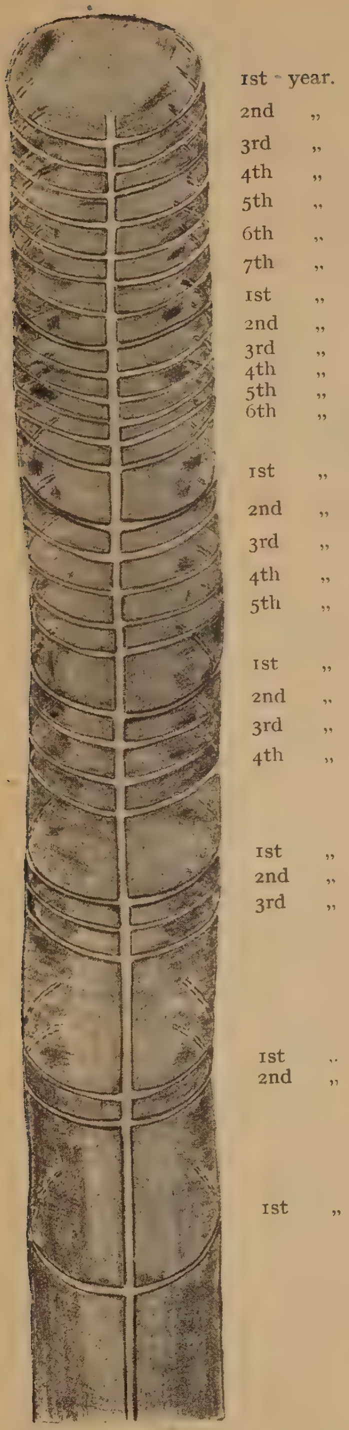
TABLE 8.

Date.	No. of trees.	Yield of latex.		Yield of dry rubber.	
		Total.	Average.	Total.	Average.
1915	979	170,220	173·87	158 lbs.	2·5 ozs.
1916	968	69,374	71·56	56 ,,	·91 ,,
1917	960	83,000	86·45	71 ,,	1·18 ,,
1918	800	62,575	78·21	57 ,,	1·14 ,,

The yields obtained in this tapping experiment are practically identical with those obtained in previous experiments and call for no special comment.

TRIAL III.—An experiment, of which tabulated results are given below, was commenced at Aburi in 1913 on 300 trees all over 17 inches in girth. The same trees (300) were tapped each subsequent year, and an additional 300 new trees brought under tapping each year up to and including 1919. The system of tapping was full herring-bone up to 100 inches from the base, the side channels extending to two-thirds of the circumference of the tree. With new trees the side-cuts were made 6 inches apart on either side of the central channel, and new subsequent cuts were made between the original cuts each year the trees were tapped.

The trees were planted in 1902 and were 11 years old when the experiment commenced.


1st year.
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3rd ,,
4th ,,
5th ,,
6th ,,
7th ,,
1st ,,
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Fig. 11.

Seven blocks each of 300 Funtumia Trees at Aburi. Planted 10 feet by 10 feet in 1902.

TABLE 9.

Yields in pounds of Rubber per acre.

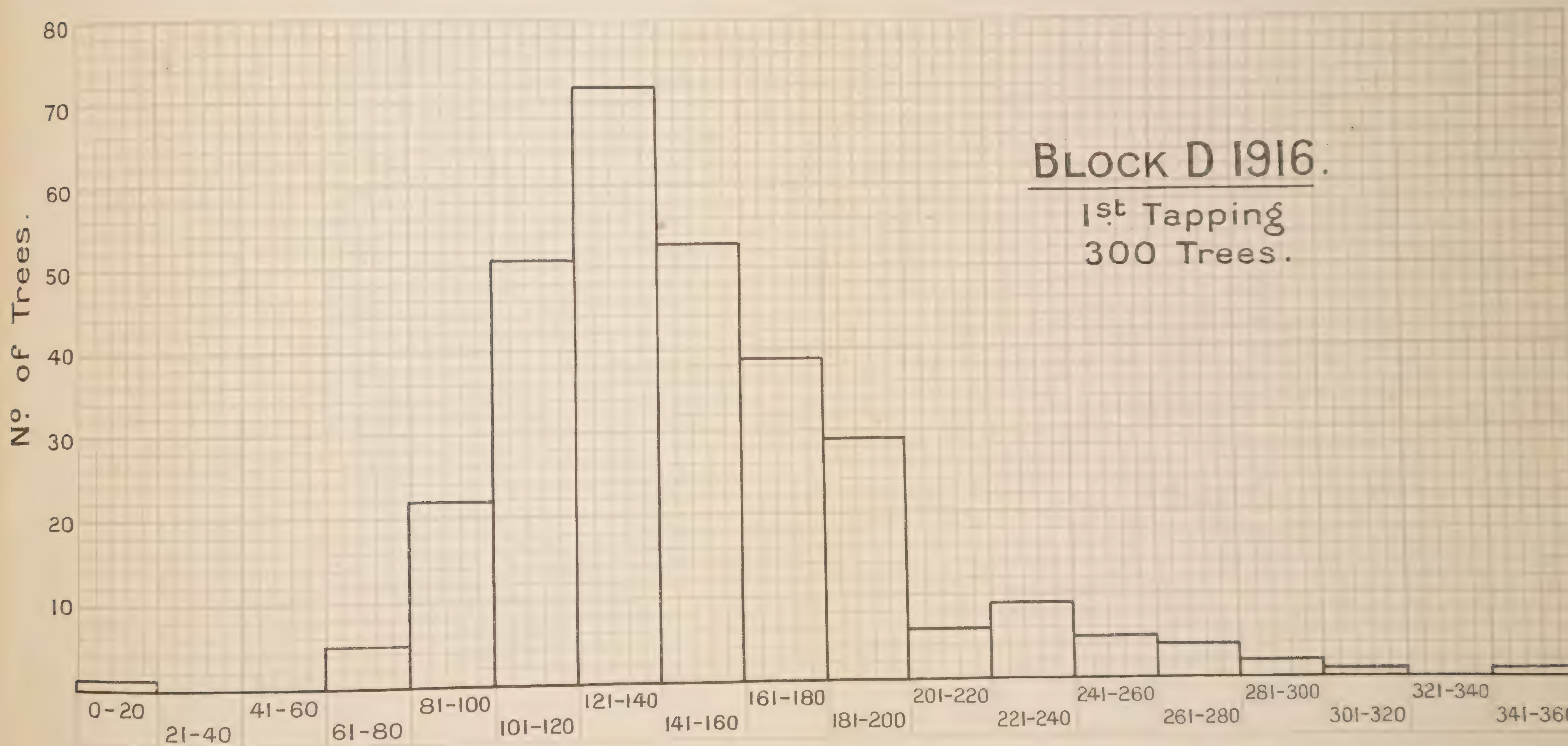
	Block A	Block B	Block C	Block D	Block E	Block F	Block G
1913	49	—	—	—	—	—	—
1914	22	44	—	—	—	—	—
1915	16	25	56	—	—	—	—
1916	13	16	22	55	—	—	—
1917	10	17	18	20	47	—	—
1918	9	6	7	7	11	26	—
1919	8	6	5	5	6	10	27

Actual details of the yields of these blocks are given in the following table :—

TABLE 10.

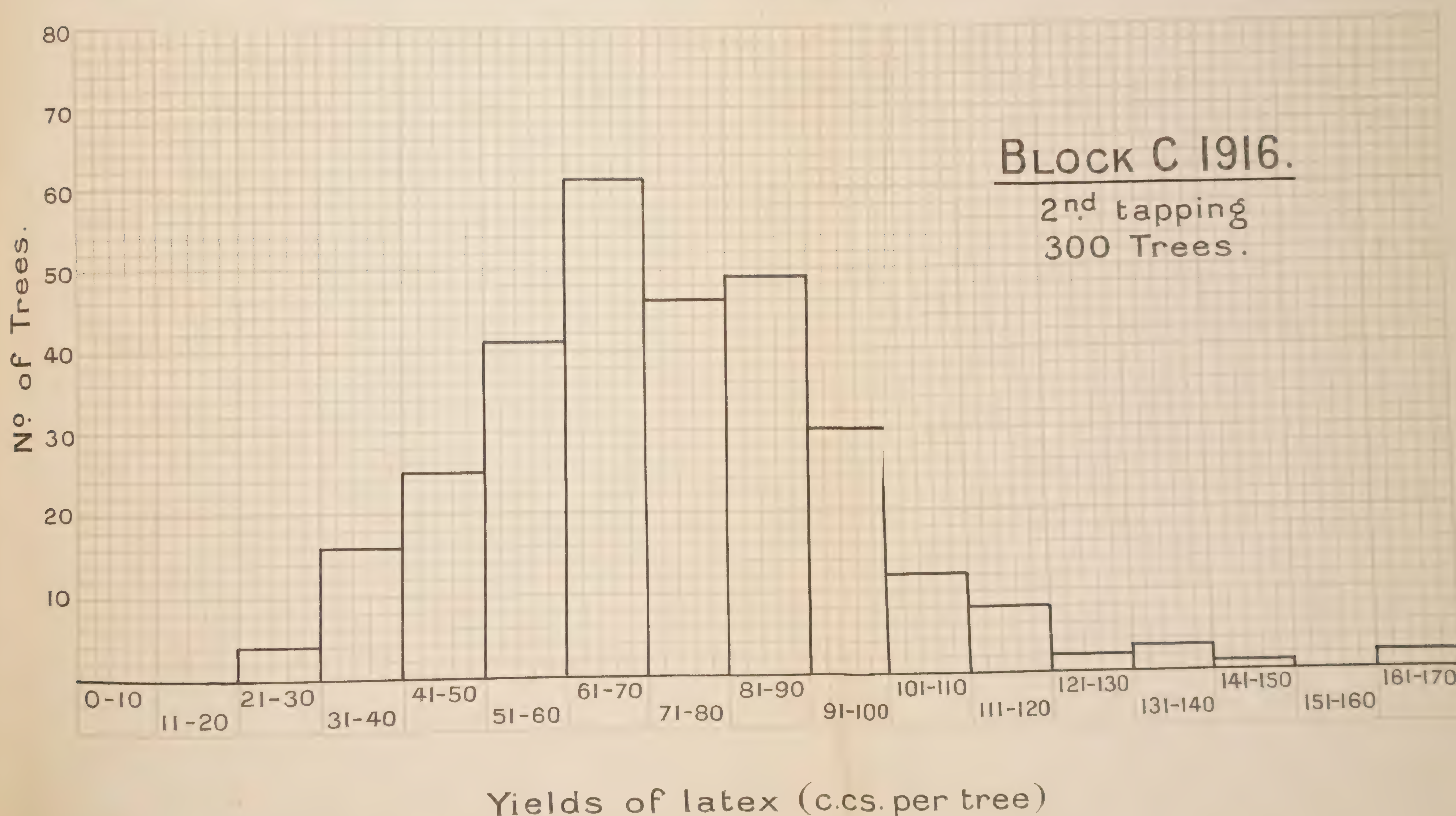
Year.	Block.	Number of trees.	Total yield, Latex in c.cs.	Total yield, Dry Rubber.		Average yield per tree.
				lbs.	ozs.	ozs.
1913	A	300	36,530	34	4	1·83
1914	,,	Do. retapped	23,237	15	8	·82
1915	,,	,,	13,850	11	0	·58
1916	,,	,,	12,743	9	3½	·49
1917	,,	,,	9,415	7	3	·38
1918	,,	,,	9,046	6	10½	·35
1919	,,	,,	7,690	5	9¾	·30
1914	B	300	35,730	30	14	1·64
1915	,,	Do. retapped	22,068	17	7	·93
1916	,,	,,	14,835	11	8	·61
1917	,,	,,	17,810	11	14	·63
1918	,,	,,	6,820	4	3	·22
1919	,,	,,	6,160	4	11½	·25
1915	C	300	42,965	38	12	2·06
1916	,,	Do. retapped	22,237	15	12½	·84
1917	,,	,,	20,090	12	15	·69
1918	,,	,,	7,575	5	—	·26
1919	,,	,,	4,490	3	11	·197
1916	D	30	44,954	38	5	2·043
1917	,,	Do. retapped	23,630	14	6	·760
1918	,,	,,	7,775	5	3½	·275
1919	,,	,,	4,080	3	12	·203
1917	E	300	46,475	32	6	1·72
1918	,,	Do. retapped	10,235	7	14	·42
1919	,,	,,	2,945	3	13	·203
1918	F	300	26,080	18	10	·995
1919	,,	Do. retapped	7,905	7	1	·379
1919	G	300	21,525	19	—	1·013

— FREQUENCY HISTOGRAM A. —



Yields of latex (c.cs. per tree)

— Frequency Histogram B. —



The yields of latex in cubic centimetres from blocks of trees which have not previously been tapped do not vary to any large degree, *i.e.* the yield from one block at the first tapping is similar to the yield from any one of the other blocks on the first tapping. These remarks also apply to the second, third, fourth and fifth tappings.

The records of individual yields of latex convey a fair idea of the decrease in yield on each occasion the trees were tapped, even though the tappings were performed only once annually.

The frequency histograms following show the distribution of trees in yield-classes. They are not strictly comparable, since to be so they should relate to one block of trees. Unfortunately, records of yields of latex from individual trees of each block for each year the blocks were tapped are not available.

Methods of Coagulation.

All the rubber obtained from the tapping-experiments previously described was coagulated either by the addition of a small percentage of Formol, Formaldehyde, Tannic Acid, or by boiling the latex. The boiling method is the cheapest and simplest, and produces a good quality rubber. Allowing the latex to stand for three or four days after it has been collected from the trees greatly facilitates the process irrespective of the nature of the coagulant used.

The quality of the rubber produced both at Aburi and Tarkwa was of good quality, as extracts from reports that are available prove. Unfortunately, both sheet and biscuits of excellent general appearance produced by machining within the past ten years were not forwarded for analysis and valuation, the excerpts from reports described below referring to biscuits produced in 1904–1906 before rubber manipulating machinery was available.

Samples of rubber from tapping-experiments conducted at Aburi were forwarded in 1904 to Dr. Weber, a well-known rubber expert, for his opinion as to the market value. The report includes the following :—

> " The samples were free from moisture. The rubber is of very good " strength, and though containing a somewhat high amount of resinous " matter, vulcanises well."

In 1905 samples were submitted to the Director Imperial Institute for analysis and valuation. They were reported on as follows :—Two samples (Nos. XI and XII) of this rubber were submitted for examination.

> " SAMPLE No. XI. Latex coagulated by exposure to atmosphere. " This sample weighed 135 grams and consisted of a single thick biscuit " of rubber which was almost black externally but showed a few white " patches internally when freshly cut. The rubber exhibited very good " elasticity and tenacity."

> " SAMPLE No. XII. Latex coagulated by boiling. The sample " weighed 128 grams and consisted of a single sheet of rubber brownish " black externally but whitish within when freshly cut. The rubber " exhibited very good elasticity and tenacity but was not quite equal " in appearance to No. XI. The chemical examination gave the following " results, and, for comparison of the two samples the figures representing " the composition of the dry material have been added."

	Samples as received.		Calculated on dry material.	
	No. XI.	No. XII.	No. XI.	No. XII.
Moisture	7·9	6·3	—	—
Caoutchouc	78·0	81·5	84·6	86·9
Resin	5·3	8·5	5·8	9·1
Albuminoid matter	7·6	3·2	8·3	3·4
Ash	1·2	0·5	1·3	0·6

" It will be observed from a comparison of these figures that the two " samples of Funtumia rubber vary considerably in the proportion of " certain constituents, although the percentages of caoutchouc in the " dry material are approximately the same. Sample XII. contains much " more resin than No. XI. but on the other hand the amounts of Albuminoid " matter and ash in No. XII. are less than half the quantities found in " No. XI. The difference in the method of preparation will, however, " account satisfactorily for the higher percentages of albuminoid matter " and ash present in No. XI. The two samples of rubber were submitted " to brokers for valuation. No. XI. was described as clean black sheet, " well prepared, and was valued at 5s. 3d. per pound (1906). No. XII. " was stated to be slightly inferior to the preceding sample and was valued " at 4s. 6d. per pound (1906)."

The rubber produced in the Gold Coast and Ashanti at the present time is a high-grade product, the production being an industry which is almost entirely carried out by the African peasant farmer or land-owner. It is as a plantation product that it is unsuitable for cultivation, chiefly on account of the low yield and the length of time that must of necessity elapse between tappings. The following by-laws are of interest in this connection :—

" ASHANTI BYE-LAWS UNDER THE NATIVE JURISDICTION ORDINANCE, 1924."

" UNDER and by virtue of the provisions of section 23 of the Native " Jurisdiction Ordinance, 1924, the Head Chief of the " Division, with the concurrence of the Chiefs, Sub-chiefs, and Headmen " and others who by native customary law are the Councillors of his Stool, " doth hereby make the following bye-laws :—

1. " These bye-laws may be cited as " The Preparation of Rubber " (Division) Bye-laws."

" 2. Every native who within the said Division shall prepare Rubber " for sale shall conform to the following directions and restrictions :—

" HEVEA BRASILIENSIS. (Brofu-aman).—To be made up in sheet form only.

" FUNTUMIA ELASTICA. (O'fruntum).—To be made up in sheet form only.

" LANDOLPHIA SPP. (Akontoma).—To be made up in string form only, and wound into balls (Ball Rubber).

" PASTE RUBBER. (Bede).—May be mixed with the latices of the following trees, plants and climbers : Fruntum, Shedua, Chenchen, Sindru, O'dum, Kakape, Amanshedua, and O'kurri.

" 3. The preparation of " AFRICAN LUMP RUBBER " is hereby " prohibited ; and any native concerned in such preparation shall be " guilty of a breach of these bye-laws.

" 4. Any native guilty of a breach of any of these bye-laws shall be " liable to a fine of five pounds, and in default of payment thereof to " imprisonment with or without hard labour for any term not exceeding " one month."

The experiments recorded embrace the whole of the experiments undertaken by the Department of Agriculture. With two exceptions they were carried out on the Aburi Agricultural Station.

Examination of results obtained proves conclusively that as a plantation product Funtumia cannot be compared to Para. The highest calculated yield per acre is only 58 lbs. of dry rubber, whereas an acre of Para of the same age will yield as much as 400 lbs. of dry rubber in one year. In addition, the older the Para tree the greater the yield, whereas after Funtumia has been once tapped the yield annually decreases. The fact that the trees annually increase in girth, and therefore present a larger tapping-area, does not appear to affect the yield from subsequent tappings.

The one point in favour of Funtumia (which is a doubtful one) is that over 50 per cent. of the total yield may be obtained on the first tapping. Against this is the undoubted fact that the trees may only be tapped profitably once per year and that the yield decreases with every subsequent tapping.

G. H. EADY,

Superintendent of Agriculture.

BULLETIN No. 15.

Department of Agriculture,
Gold Coast.

THE CLIMATOLOGY
OF
THE GOLD COAST.

BY

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1928.

TABLES.

* Tables II.—XIII. at end of Bulletin.

LIST OF PLATES.

The Climatology of the Gold Coast.

PART I.

INTRODUCTION.

(This Bulletin was submitted before publication to the Director of the Meteorological Office, Air Ministry, London, and the valuable suggestions made by him were incorporated in the text. The writer wishes to record his grateful acknowledgment of the Director's kindness in the matter.)

Climatology or geographical meteorology is the study of the average meteorological conditions in a country or continent. The word is derived from the Greek word "Clinein" meaning to incline, referring to the inclination of the earth's axis. "Clima" or clime meant originally difference in latitude and, since there was a marked difference in meteorological conditions according to latitude, the climate refers now to these conditions rather than to variation in latitude alone.

Meteorology refers to the physics of the atmosphere and is concerned with the actual instruments and records from them, the laws governing the weather, and the accuracy of the instruments. Climatology deals chiefly with the collection and arrangement of the records in order to describe from them the reasons for the climate.

For the purposes of this Bulletin the sciences are considered under the greater heading since neither can be complete without the other. The relation of the climate to agriculture is discussed in Part VII.

As far as possible the various factors are considered in logical sequence and the methods of recording each factor are discussed together with their effect on climate in general and the Gold Coast in particular. While all the factors are more or less inter-dependent, the chief, as far as agirculture is concerned, is undoubtedly the rainfall which is therefore discussed at greater length and in more detail than the others. Such factors as clouds and wind, which are recorded without instruments and as a rule regarded as of small importance, are given at some length because they are better guides to the climatology of a country than to the meteorology of a single observation point. For instance the movements of clouds give an indication of the high level winds which are outside the range of such meteorological instruments as are usually found on stations, but which have nevertheless an important bearing on the climate.

PART II.

PHYSIOGRAPHY AND CLIMATE.

The contours of elevation of the earth's surface, and the position of the country relative to large masses of water have a very large effect on the climate of the country.

The centres of continents being at a distance from the oceans have usually a much lower rainfall than countries with a seaboard, especially where there is mountainous country between them and the direction of the prevailing winds. The Sahara and Kalahari deserts of Africa and the Central deserts of Australia and Turkestan in Asia are cases in point.

The position of the Gold Coast in the relation to the Atlantic Ocean assures it of a reasonable rainfall during the period of the monsoon winds from the south-west. A wind constantly blowing from the north-east at low levels would come from the dry central deserts and would render the country barren in a very short time.

It is usually found that the meteorological conditions of a country follow the orography very closely. The lines of equal rainfall or isohyets will be determined by the direction of the prevailing winds and position of mountain-ranges. The majority of the rain should fall on the weather-side of the ranges and the country on the lee side of the ranges will be much drier in consequence.

The air having to ascend in order to pass over the mountains is subjected to a less pressure, consequently it expands and becomes cooler. The lower the temperature of the air, the less water vapour it can hold and, consequently, rising air, which was originally saturated, must lose some of its water in the form of rain. Having passed over the mountains the air ceases to rise and tends to descend, which causes it to be warmed by compression and increases its capacity for moisture. Hence the weather-side of mountains tend to be rainy, the lee sides dry. The same effect is seen where a wind from the sea strikes the coast, even where the latter be low, owing to the greater resistance to the wind offered by the land surface as compared to the water surface.

In the Gold Coast it is observed that a heavy deposition takes place on the south side of the Kumasi-Aburi range, but that, actually, the heaviest rainfall is found in the south-west corner around Axim. At this point the coast trends towards the south-east and the rain bearing south-west, winds strike it at right angles. The rainfall of this part of Africa normally decreases with increasing distance from the equator and hence the rainfall of the Axim coast is greater than that further north in spite of its lower elevation.

The remainder of the isohyets for the country have their focus from this point and run parallel to the range.

From this it appears that the range is a definite factor in determining the zones of rainfall (*see* Plate XI).

The isotherms or lines of equal mean shade temperature also follow the configuration of the country and show the same parallelism as the isohyets but in the reverse order, the area of greatest rainfall and least rainfall being practically the same as the areas of least temperature and greatest temperature respectively (*see* Plate XII).

It is impossible, owing to the almost complete absence of barometric readings, to state whether the isobars or lines of equal pressure would also show this parallelism.

Relation to the rest of West Africa.

The Gold Coast has a much lower rainfall than any other part of the West Coast, with the exception of Togoland. The greatest mean annual precipitation is 75 inches whereas the figures for Sierra Leone, Liberia, Ivory Coast and Nigeria are far greater. The majority of Sierra Leone and Liberia is within the 100 inch zone, whereas on the slopes of the Cameroon mountains the average annual fall rises to 400 inches and in some years this is exceeded.

This is explained by the fact that the mountains come right down to the sea in these areas and the rapid rise of the air, immediately on passing over the littoral, in order to attain a height sufficient to be able to get over the mountains, causes an excessive deposition in the countries named.

In the Gold Coast the mountain-ranges are lower and further from the sea than in these countries and as a result the rainfall is lower in amount.

Where rainfall is excessive the mean temperature tends to be lower and the temperatures recorded in Sierra Leone and the Camaroons are lower than those in the majority of the Gold Coast. The average shade maximum and minimum temperatures of the Gambia are equal to those on the Gold Coast but the rainfall is much lower owing to its lower altitudes.

It is stated that the central belt of Africa from 10° N. to 20° N. is gradually drying up. Records of rainfall are not obtainable for a sufficient period to prove this point but several facts seem to point to this as being possible. Forty years records from the Gambia Colony show a diminution when taken in decades of from 54·17

inches to 44·70 inches. The Cape Verde Islands, visited by the writer in 1921, had had such little rainfall that vegetation once luxuriant was very nearly wiped out. The records from the Northern Territories of the Gold Coast, although only available for 15 years, show a diminution at Tamale and at Kintampo in Ashanti of from 44·42 inches to 40·80 inches and from 75·33 inches to 64·57 inches in five year periods; whether this is seasonal fluctuation or not it is hard to say, but from reports by constructional engineers it appears that the Gold Coast is in line with the rest of West Africa and that the central desert may be gradually spreading towards the coast.

Climatic Zones.

The whole of the Gold Coast Colony and the Northern Territories lies within the Torrid Zone between the latitude of 5° and 11° North of the equator.

In the extreme north above the limit of the Northern Territories is the *zone of tropical climate* characterised by a long dry season and a single rainy season with wide ranges of temperature. The passage of the sun towards the Tropic of Capricorn and its return towards the south are almost coincident with the limits of this zone.

The Northern Territories lie on the *Sub-equatorial Zone* and there are two rainy seasons without a very marked break. This break becomes less and less marked as one proceeds northwards till at Navrongo there appears to be little if any evidence of this break. The temperature still has a wide range and the Harmattan is severe with a wide range of Humidity.

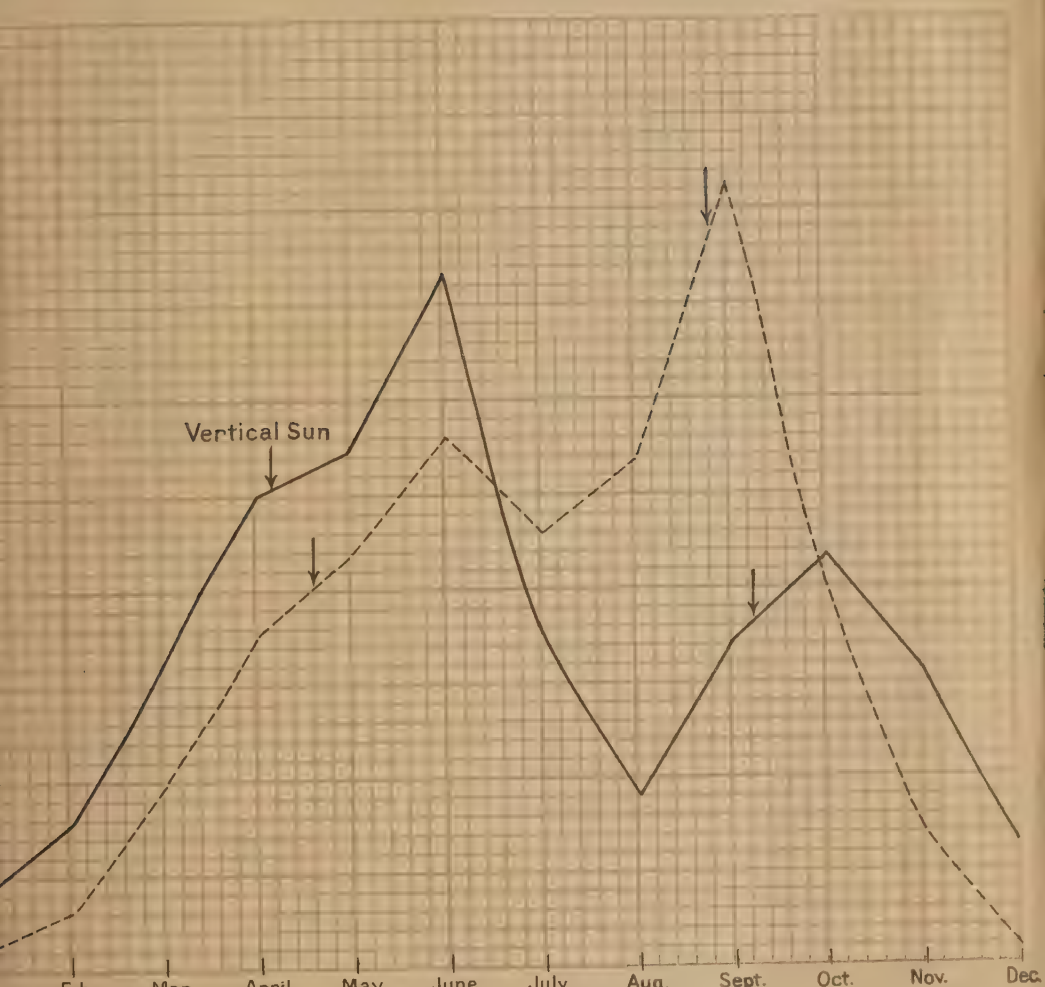
The *Equatorial zone* covers the whole of the south below a line drawn from Sunyani to Kete Kratchi except for a strip of Coastal Savannah, and has a marked double rainy season with less range of temperature. The passage of the sun being at intervals of five months is the cause of the two rainy seasons (*see* Plate I.). Humidity is high except on the coastal belt during January and February.

Chipp, in "The Forest Officers' Handbook of the Gold Coast, Ashanti and Northern Territories," differentiates these zones as :—

1. Coastal Savannah	Sudanese zone.
2. Deciduous Forest	Guinea zone.
3. Wet Forest	
4. Transitional	
5. Parkland and Inland Savannah ...	Sudanese zone.

MONTHLY DISTRIBUTION OF RAINFALL.

As percentages.



——— South of Mountain range

- - - - North ,, ,, ,,

The Guinea zone is analogous with the Equatorial and the Sudanese with the sub-equatorial zone.

(1) *Coastal Savannah.*—This extends right along the coast from end to end of the Colony, and is usually a strip 10 miles broad, except at Axim, where the forest approaches to within 2 miles or less of the coast, and from Ada to the French Togoland border, where it merges with the Parkland and there is no intervention of the Guinea Zone. Except near Axim the area is one of low rainfall (25–40 inches), with comparatively high temperatures, but, being coastal, there is a high humidity and very small variation in the readings of the thermometers.

(2) *Forest.*—The forest is being definitely diminished in area from the Coast and becoming smaller on all sides due to the spread of cacao-farming and civilization generally.

The shifting system of cultivation whereby a man opens up new farms yearly by felling forest and planting, first food crops, and after that cacao, is largely the cause of this. Every year the farmer seeks new food farms and fells the forest trees to obtain them. The forest extends from the coastal savannah to the Kumasi-Aburi hills, and includes all the Western Province, the majority of the Central and Eastern Provinces, and part of Ashanti. There is a large precipitation of rain with a high humidity and a lower average temperature.

(3) *Transitional and Deciduous Forest.*—This is a belt encircling the forest between it and the coastal savannah of the south and the parkland of the north and east. Wherever deforestation is taking place, secondary bush is springing up and the savannah gradually encroaching. Kintampo was once undoubtedly in the forest zone, but has now to be placed in the transitional. Nsawam is another case. Isolated trees representative of the close wet forest may still be seen standing in this zone, proving that at one time it was part of the forest.

The northern part of Ashanti falls in this area, together with part of Togoland.

(4) *Parkland and Inland Savannah.*—This zone is characterised by open grass country with few trees and these of a definitely different type. In the extreme north the shea-butter nut tree (*Butyrospermum Parkii*) is characteristic.

The Northern Territories and the majority of Togoland are in this area, which is one of low rainfall, low humidity, and high temperature. There is an average range of 20 degrees between shade maximum and shade minimum thermometric readings.

The climatic zones were differentiated by Auchinleck in Bulletin No. 2 of the Department of Agriculture according to the degrees of wetness recorded at stations (*see* Part V, page 21 of this Bulletin).

1. Wet Group.
2. Upper Medium.
3. Lower Medium.
4. Dry Group.

These correspond roughly to the other system as shewn in Table I below.

TABLE I.

SYSTEMS OF CLIMATIC ZONES.

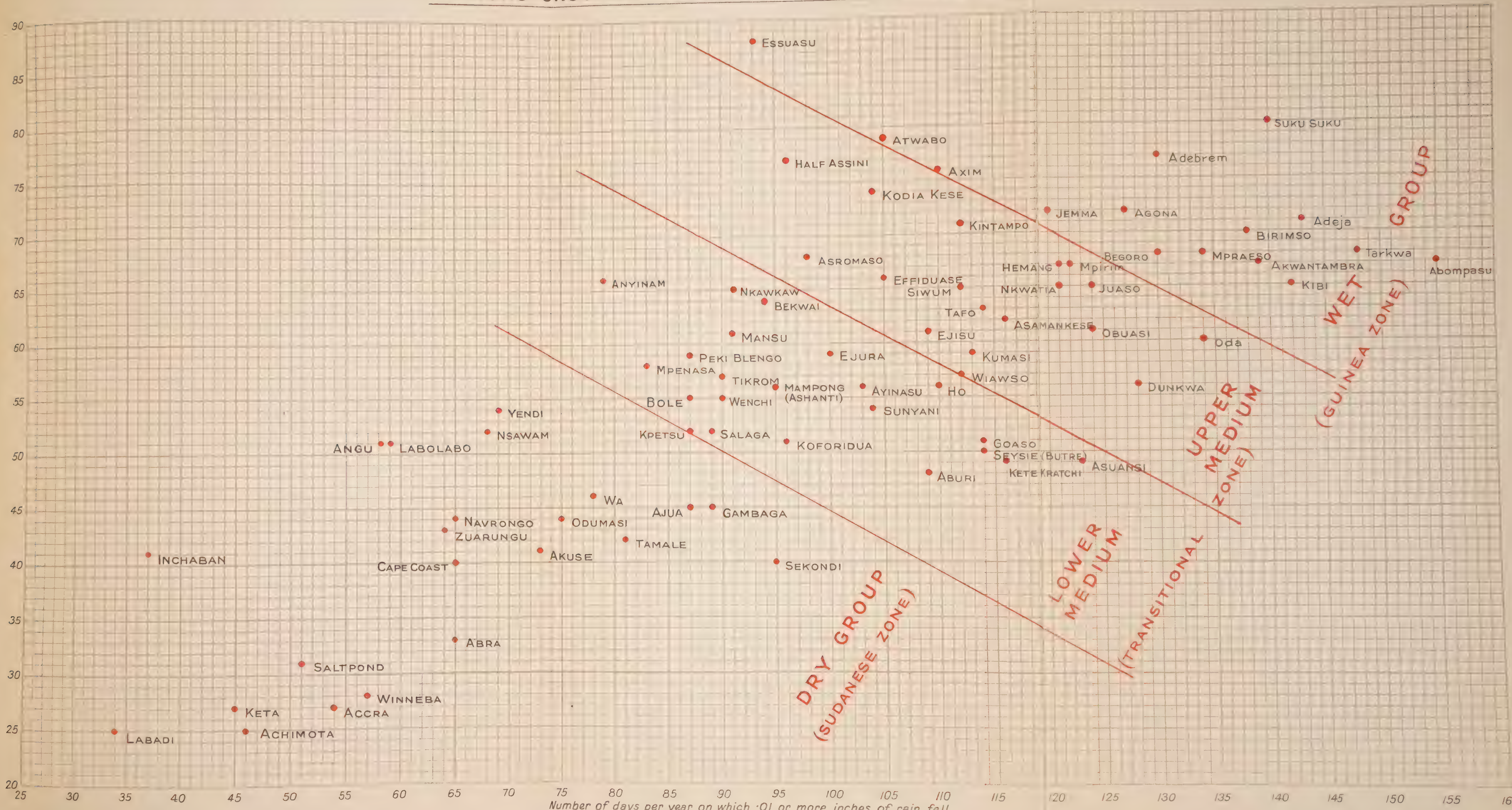
Geographical.	Chipp.	Auchinleck.
Torrid zone.		
(A) Tropical ..	Not represented ..	In the Gold Coast.
(B) Sub-equatorial	Sudanese..	Dry Group.
(C) Equatorial ..	Guinea	Wet Group.
	Transitional	Medium Group.

The chart representing the classification according to degrees of wetness is reproduced as Plate II and will be discussed in Part V under Rainfall. It is sufficient here to make the comparison between the different types of classification. The systems agree in the majority of cases since the types of vegetation met with are dependent on the rainfall. There are of course, stations which appear to be out of place but certain of these cases in which the records have been proved as correct, appear to be abnormalities and to represent a transitional phase in their meteorological conditions.

Agricultural crops of importance occur mainly in the Guinea or Wet zone and are cacao, cola, coffee, oil-palms and rubber. The main products of the Sudanese or Dry zone are shea-butter, sisal, cotton and copra. Of the five main agricultural exports from the Gold Coast four, cacao, cola, palm-oil and kernals, and rubber come from the Guinea zone and one only, viz., copra from the Sudanese.

It may be argued that the majority of the Sudanese zone is outside the limits of economic transport but the possibilities of agricultural crops in this zone are much lower than in the Guinea zone unless an enormous cotton industry could be profitably organised.

STATIONS GROUPED ACCORDING TO DEGREES OF WETNESS.



PART III.

METEOROLOGICAL STATIONS.

A complete list of the meteorological and rainfall stations of the Gold Coast is given in Table II together with their distribution according to climate zones.

As is to be expected, the majority of the major stations lie in the coastal area where there is more civilisation and observers are more readily obtained.

Although it has been possible to open recently more stations in other parts of the country where information is needed, yet the whole distribution is dependent on there being observers available.

Records are being obtained from private individuals, missions and by observers belonging to the following Government Departments :—Agriculture, Customs and Preventive, Education, Medical, Political, Public Works and Railways. The continuity of records depends on whether there is a resident observer in any one station and records have had to be broken occasionally owing to movements or sickness of officers.

Classification of Stations.

Three classes of stations are recognised by the Meteorological Office.

(1) *First Order Stations of the International Classification.*—Normal Meteorological Observatories at which continuous records or hourly readings of pressure, temperature, wind, sunshine and rain with eye-observations at fixed hours of the amount, form and motion of clouds and notes of the weather are taken.

(2) *Second Order Stations of the International Classification.*—Normal Climatological Stations at which are recorded daily, at two fixed hours at least, observations of pressure, temperature, wind, cloud and weather, with the daily maxima and minima of temperature, the daily rainfall and remarks on the weather.

(3) *Third Order Stations of the International Classification.*—Auxiliary climatological stations at which the observations are of the same kind as at the Normal Climatological Stations but are (*a*) less full, or (*b*) taken once a day only or (*c*) taken at other than the recognised hours.

The instrumental equipment of a Normal Station consists of :—

1. Mercury barometer reading to ·1 millibar or ·002 inch.
2. Dry bulb thermometer } In Stevenson Screen.
3. Wet bulb thermometer } In Stevenson Screen.
4. Maximum shade thermometer } In Stevenson Screen.
5. Minimum shade thermometer } In Stevenson Screen.
6. Rain-gauge.
7. Sunshine recorder.
8. Solar maximum thermometer } Not essential.
9. Grass minimum thermometer } Not essential.
10. Earth or soil thermometers } Not essential.

The meteorological stations in the Gold Coast are of the third order mentioned above except that they do not have barometers, save at Accra and Kumasi, but they have Solar maximum and Grass minimum thermometers.

Accra station possesses in addition to the above instruments, a thermograph, barograph, electrical contact anemometer and a Campbell-Stokes sunshine recorder.

Daily observations are made at all stations at 9 o'clock G.M.T.

It is hoped in the near future to make five complete stations of the second order at least and to make the headquarters station a first order meteorological observatory where research work may be undertaken.

Distribution of Stations.

The distribution of stations according to their order and climatic zones will be found in Table II.

(a) *Meteorological.*—There have been twenty-one meteorological stations from which records are available. Of these, six are closed except for rainfall records and two others are so recently opened that records from these (Kpeve and Achimota) are not included in the tables.

The fifteen stations remaining open are distributed as follows :—

Coastal savannah	Five
Forest area	Six
Transitional	Two
Inland savannah	Two

The closed stations were distributed in following areas :—

Coastal savannah	Three
Forest area	None
Transitional	None
Inland savannah	Two

From this it will be seen that the comparatively unimportant coastal area has been deprived of stations to give these to the districts of greater agricultural importance.

(*b*) *Rainfall.*—The rainfall stations, *i.e.*, those where a rain-gauge only has been installed and from which records are available, are 85 in number, of which 17 have been closed, leaving 68 in operation. This figure includes the 15 meteorological stations which all record rainfall.

The majority of these are situated in the forest area, which is most important since it is the cacao-growing country, and the remainder are distributed as far as possible to indicate the general distribution of the rainfall and to link up with the isohyets of the Ivory Coast and Togoland.

PART IV.

TEMPERATURE.

The mean annual temperatures in the shade and sun are given in Tables VII and XII for all stations, and it will be noticed that these are lower than is usually supposed. The West Coast of Africa has had an unenviable reputation for climate in the past but this is not attributable in main to the temperature but rather to the excessive humidity.

Insolation.

This is the term by which scientists designate the exposure to the sun's rays. The period of insolation varies with the length of the day and the intensity with the latitude as well as the declination of the sun, so that the lack of intensity in temperate climates as compared with the Gold Coast is, to some extent, compensated for during the summer months by the greater period of insolation.

The sun becomes vertical over the Gold Coast twice in the year. This occurs in Accra about April 4th*, and September 8th*, and on the Northern Frontier about April 19th*, and August 24th*. The passage of the sun towards the solstices has a very great effect on the climate as regards the distribution of rainfall and the occurrence of the dry season of harmattan (q.v.)

The intensity and duration of insolation is recorded at Accra by means of a Campbell-Stokes sunshine recorder. The instrument consists of a globe of crystal glass which concentrates the rays of the sun on to a strip of cardboard divided into periods of hours and half-hours. The burning of the card gives the duration of the sunlight and the extent of the burned portion gives a rough idea of the intensity.

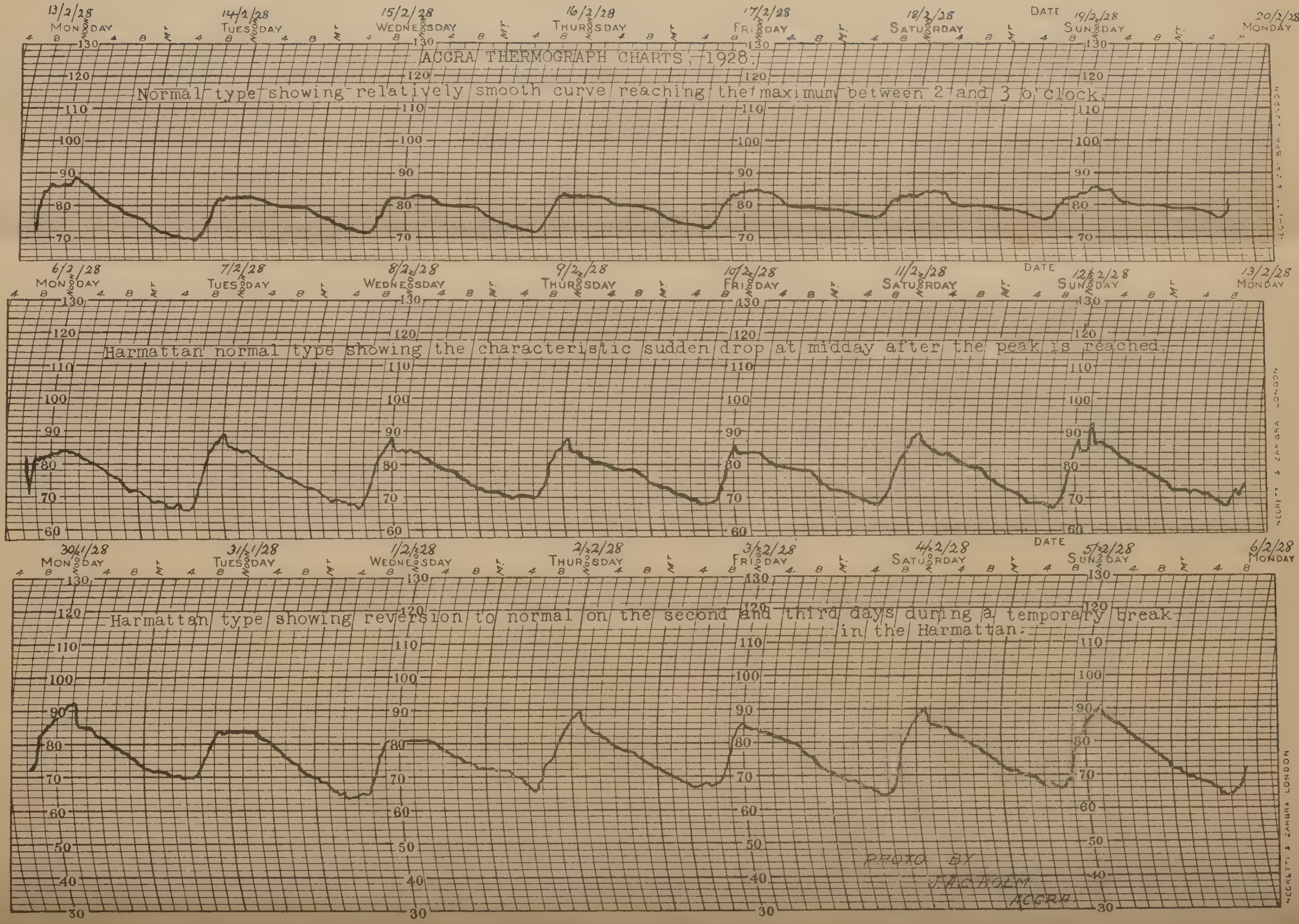
These records have been arranged in the form of an isopleth diagram giving the distribution throughout the year of lines of equal insolation. The period of greatest insolation is in December and January when the dry season is at its height and the minimum is reached at the periods shortly after the sun is vertical, which corresponds with the overcast condition of the sky in the wet season.

Solar Maximum Temperature.

The maximum temperature in the sun is recorded at all stations and shows little variation in the averages for the country as a whole. It is highest in the open country of the Northern Territories, Togoland and the coastal strips and may be stated to vary between 135° and 160° with an average of 145°. The forest area shows

* 1927 figures.

PLATE III.


ACCRA THERMOGRAPH CHARTS, 1928.
Normal type showing relatively smooth curve reaching the maximum between 2 and 3 o'clock.
Harmattan normal type showing the characteristic sudden drop at midday after the peak is reached.
Harmattan type showing reversion to normal on the second and third days during a temporary break in the Harmattan.
PHOTO BY J. A. CHOLM ACCRA
NEGRETTI & ZAMBRA LONDON

lower figures of between 120° and 145° but individual extremes vary outside these limits. While these temperatures are high enough to render the use of sun helmets necessary, they are not excessive when compared to those in other tropical countries.

Shade Temperatures.

The thermometers giving the maximum and minimum temperatures in the shade are exposed to the air in a Stevenson screen of standard pattern or suspended in a cage under a thatched roof. Which of these methods is most suited to tropical climates is a debatable point and opinions differ. At one time the thatched roof was considered essential but recent research appears to favour the Stevenson Screen, which has been declared as the standard method of exposure in India.

From the maximum and minimum shade readings the mean shade temperature is got by addition of the two and division by two.

The monthly mean distribution of temperature and the annual means are given in Tables VII–XII for all stations.

The monthly variations show a more or less steady curve with the maximum in the early months of the year and the minimum in July-September, which corresponds inversely with the distribution of humidity and rain.

The widest range of temperature is in January or February during the harmattan season when the days are hot and the nights comparatively cold.

The variation of temperature from place to place is in accordance with ordinary climatic laws, the highest temperature and widest range occurring in the Northern Territories while the variation and range on the coastal strips is slight owing to the influence of the sea.

Generally speaking, the shade temperatures show but small variations compared to those recorded in temperate climates and although in the savannah country individual maxima of 100° and over are recorded, the usual range is from 75°–90° for the maximum and 60°–75° for the minimum thermometer.

Compared to other tropical countries such as India and Central America where shade minimum readings of 80°–90° are not uncommon the climate of the Gold Coast appears to be pleasant.

The mean shade temperature may be averaged at 85° for the open savannah of the North and East and 80° for the South.

The Thermograph.

This instrument, which is a self-recording thermometer, is situated in the screen together with the maximum and minimum shade thermometers and the hygrometer. Being a delicate and expensive instrument, it is provided at Accra only.

It records continuously and from its records the diurnal variation and range of temperature and also the temperature at any one moment may be read off. One chart lasts for a week and by preserving the weekly charts, a complete annual record may be obtained. It is obvious that the records from such an instrument are far more valuable than those of a thermometer read once or twice daily as there may be a vast change from hour to hour between the readings of an ordinary instrument.

The daily range of temperature in Accra is found to be very constant throughout the year (*see* Plate III) and to vary only when a storm approaches, when a very rapid drop occurs. This drop is shown on the tracing as an almost perpendicular line which returns gradually to the normal. The daily average range is 12° with a minimum just before sunrise and a maximum at 3 p.m.

During the harmattan season, however, the range is greater and the curve is of a different shape (*see* Plate III, Fig. 2). The peak of the curve is earlier and occurs at 12 noon instead of at 3 p.m.

Terrestrial Minimum Thermometer.

This instrument, which is placed on a support just above the level of the grass, gives an indication of the lowest temperature reached by small objects, such as plants, exposed on the surface of the earth. Where the air is dry and the sky is clear, the readings are generally considerably lower than the shade minimum. The fact that, in the Gold Coast, the difference is small indicates that there is little free radiation to the sky.

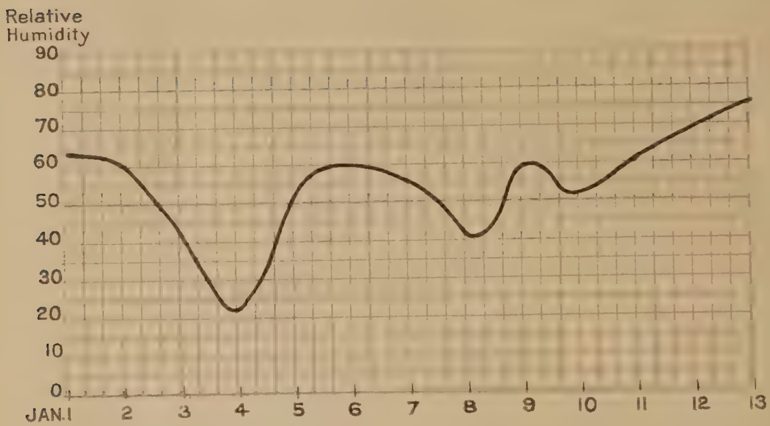
It is a thermometer which is more often the cause of trouble in maintaining efficient readings than any other instrument since the exposure to the sun's rays appears to cause a frequent breaking of the column of alcohol. It is recommended that this thermometer be brought inside during the day as it is unlikely that the temperature would reach a minimum during this part of the twenty-four hours.

It is very liable to the " tiring " referred to in Appendix B.

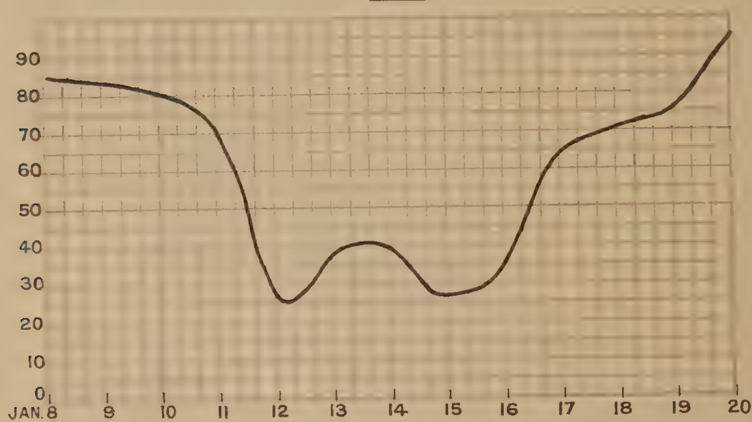
THE HARMATTAN, ACCRA.

Diminution of Relative Humidity of the Atmosphere.

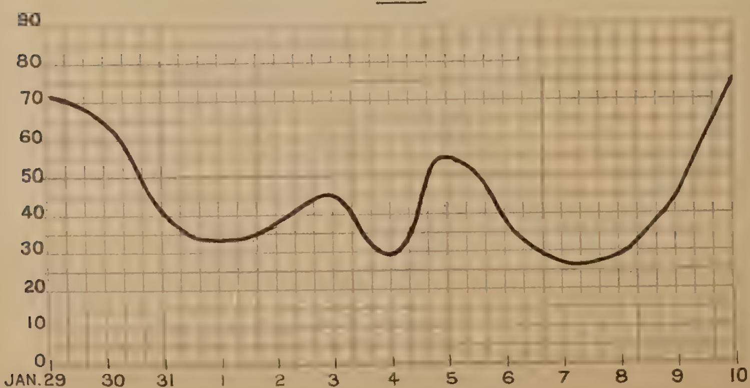
1926.



1927



1928



PART V.

MOISTURE.

The humidity of the atmosphere in the Gold Coast is the most characteristic feature of the climate and the cause of the feeling of slackness which the European has to experience when living here. It is apparent on entering the forest country by means of the mouldy or musty smell which pervades the whole area and is probably what was alluded to in the old days as the "malarial miasma." The difficulty with which scientific specimens, clothes and other material may be kept free from mould is a sign of the high percentage saturation of the air.

Relative Humidity.

The relative humidity of the atmosphere is the percentage ratio of the moisture content of the air to that of saturated air at the same temperature and is determined by calculation from the difference between readings of the dry and wet bulb thermometers in the Stevenson screen or the cage as the case may be.

These thermometers are mercurial instruments of ordinary type, one of which has a muslin cover over the bulb to which is attached a cotton wick leading to a water container. By this means, the bulb is kept continually wet and the evaporation of the water gives a lower reading than that of the dry bulb. Obviously, the amount of the evaporation and the consequent temperature of the thermometer will vary in accordance with the saturation of the atmosphere surrounding it.

The calculation of the relative humidity from the readings of these thermometers is effected by means of calculated hygrometrical tables from which the figure for the relative humidity is read off. This figure is a percentage expression of the saturation of the air. If the air contained as much invisible moisture in the form of vapour as was possible under the existing conditions of temperature and pressure the readings of the two thermometers would be the same since the cooling effect of the evaporation of water from the surface of the muslin surrounding the bulb of the wet bulb thermometer would be nil. There is always a tendency to the state of equilibrium between the moisture content of the air and that of objects over which it is passing, hence completely saturated air would have no effect on the reading of the wet bulb thermometer.

Readings of 100 per cent. relative humidity have been recorded during the wet season but the average lies between 60 per cent. and 70 per cent. in the Northern Territories and between 80 per cent. and 90 per cent. in the south. During the harmattan season (q.v.) the reading drops to below 20 per cent. and often within a period of 24 hours (*see* Plate IV).

It is this high humidity which renders the Coast so enervating to the European and which makes it so much more unhealthy than tropical climates with a much higher mean temperature.

On the other hand cacao is successfully grown on the Gold Coast with a rainfall much less than is usually considered satisfactory, simply by the reason of the humid atmosphere.

The actual humidity of the air varies considerably at different altitudes and it has been recently shown by Jaumotte in Belgium that the humidity drops very considerably at heights up to cloud level. This is consistent with observatons by mountaineers but it must be remembered that the atmosphere actually within the clouds is at saturation point or 100 per cent. humidity. It is necessary to compare the humidities at different heights on the same station in order to show the diminution, since the moisture-content of different stations will obviously vary according to the altitude and average rainfall at each.

The relative humidity recorded by instruments only holds good for the immediate time of observation and then only in the vicinity of the instruments. It will obviously vary from hour to hour due mainly to variations in temperature and the diurnal variation is very considerable, especially during incidence of storms.

The observations at Accra Meteorological station when compared with those recorded at the Medical Department Analytical Laboratory situated about half a mile distant inland have, however, been very consistently close.

The principal action of the moisture in the air is to restrict access of heat to the earth from the sun and also the radiation of heat from the earth. This explains the equable temperature of the Gold Coast and extremes of temperature usually occur during periods of low relative humidity such as are experienced during January and February.

The Dew Point.

Dew is formed by the condensation of atmospheric moisture on a surface cooled by loss of heat during the night. The earth is no longer receiving heat but is radiating from its store and therefore cools not only its own surface but the surrounding air. The temperature at which such condensation takes place is called the dew point and will vary according to the amount of vapour pressure and the temperature during the day, in as far as the latter affects evaporation.

It is calculated by reference to tables which give for each degree of temperature of the dry bulb thermometer the amount to deduct from the reading of the wet bulb.

If the dry bulb reading be 80° and that of the wet bulb 72° we find that, on consulting the tables, the figure opposite to 80° and under 8° (the difference of the two readings) the figure 5·4° so that the temperature of the dew point will be 72–5·4 or 66·6°.

A crude approximation of the dew point may be made by allowing three-fifths as many degrees below the wet bulb reading as that reading is below that of the dry bulb.

Precipitation of Moisture.

The moisture which is present in the air as aqueous vapour returns to the earth in many ways, viz., dew, fog, mist, rain, hail or snow. The last is not encountered in the Gold Coast and is therefore outside the scope of this paper.

Dew.—This is a common phenomenon in the forest country as is natural. When the dew-point is approached the formation of dew is most evident where there are a small number of radiating surfaces such as are provided by vegetation. It is not uncommon when passing through forest in early morning to be soaked by an apparent shower, although the sky may be clear. This is the falling of the dew from the leaves of the trees where dew has condensed during the night.

The average annual amount of dew which falls is not estimated to be more than 1·5 inches.

Mist and Fog.—Water vapour is transparent, but when condensation takes place in the air itself minute drops of rain are formed which are sufficiently light to remain suspended, but which break up the passage of light waves and become visible as mist. The ordinary glass of commerce is transparent, but powdered glass is opaque and a similar situation occurs in the condensation of water. It is not understood what force causes these drops to coalesce and form rain, but it may be electrical in nature.

Mists and fogs are common in the hilly districts of the forest zone, especially at such places as Aburi, Asuansi and in the Togoland hills. They assist in cacao-growing by providing a moist atmosphere and by preventing desiccation of the soil. They persist sometimes all day and often till almost mid-day.

Rainfall.—This is a very important factor in the distribution of the agricultural crops of the Gold Coast. The records and distribution of rainfall in this country have been the subject of several publications.

Chipp, in the Forest Officers' Handbook of the Gold Coast, and later in "The Gold Coast Forests," discussed the distribution,

while Auchinleck in " The Rainfall of the Gold Coast " (Department of Agriculture Bulletin No. 2) summarised the records and produced a map of isohyets.

As mentioned before (p. 13) there are 68 stations in the Gold Coast where rainfall is recorded and an effort is being made to obtain records in new districts where observation appears necessary in order to clear up difficulties with regard to the actual path of the contour lines.

The contour map has been revised annually since it was first published in 1924 and there appears, in the light of three years' additional observations, no reason to doubt that the main features are correct. Figures have been obtained recently from the German records in Togoland and the French records in Ivory Coast and the French Sphere of Togoland, and these appear to bear out the contours as set out in the present map (Plate XI).

Mean Monthly distribution of Rainfall.—The mean monthly precipitaion for all stations is given in Table XIII. The stations are listed in order of their records and are not in geographical distribution.

All records are given even where stations are now closed in order to give the fullest information possible. Even though variations of considerable magnitude take place in any one year, an approximate idea of the probable rainfall in any one month can be obtained from these records.

It is impossible to give actual records for each station, even if any good purpose were served by such records, as their tabulation would be bulky and of little real value.

It will be noticed that definite rainfall seasons are shown in these tables and these are clearly demonstrated in Plate I, where the distribution in the Northern stations (Sudanese zone) are compared with those in the Southern stations (Guinea and S-Sudanese zones). It is plain that the seasons fall in the period just after the northerly or southerly passage of the sun towards the solstices. There seems little doubt that the monsoon wind is dependent on the apparent movement of the sun and that the distribution of rainfall is the outcome of this.

Annual Variation of Rainfall.

The mean annual rainfalls for all stations are shown in Table XIII, and range from 88·00 inches in the case of Essuasu to 24·54 inches in the case of Achimota.

Many attempts have been made in the past to see whether or not the rainfall of any one station or country shows a definitely periodical recurrence of wet or dry seasons.

ANNUAL PERIODICITY OF RAINFALL.

Climatic and rainfall oscillations were believed to run in eleven-year periods coincident with and dependent on the distinct eleven-year periodicity in sun-spots, but records have failed to be universally emphatic on the point.

Meldrum in Mauritius found some periodicity in rainfall figures coincident with sun-spots, and found that cyclones and the heavy rainfall associated with them were most frequent in years of sun-spot maxima.

There are only two stations in the Gold Coast where records have been kept long enough to throw any light on the point, viz., Accra and Aburi. The periodicity curves for these two stations for 41 and 47 years respectively have been worked out, but show no periodicity of this kind. (*See* Plate V).

Buickner's 35-year periodicity hypothesis, which is coincident with Lockyer's statement of a 35-year cycle in solar activity, is of too long periodicity to be of use in finding a periodicity in rainfall in this country, as our records are too short in duration to give such indications.

It will be noted from Plate V that, whereas in Accra 1926 and 1927 were dry years, in Aburi these years were just above the average, but as a general rule the charts bear resemblance in wet and dry periods.

Degrees of Wetness.

The degrees of wetness are empirical figures derived by multiplying the number of inches of mean annual rainfall by the number of wet days. The wet day is a period of 24 hours within which ·01 inch or more of rain falls.

This may be reduced to a formula as under :—

$$\text{D.W.} = \frac{R \times D}{100}$$

where R = mean annual rainfall
and D = number of wet days.
D.W. = degrees of wetness.

This method of showing not only the total precipitation but also the distribution of fall was adopted by Chipp in his Forest Officers' Handbook of the Gold Coast, Ashanti and Northern Territories, as being more reasonable and descriptive of conditions than total rainfall.

Auchinleck, in "The Rainfall of the Gold Coast" (Bulletin No. 2 of the Department of Agriculture), also adopts this classification of rainfall with the difference that the stations on the chart (*see*

Plate II) are in groups according to rainfall, and not according to their botanical features. The present chart has been re-drawn to include the latest figures and has been made to include both systems of classification.

This system of grouping indicates very clearly the crops and types of cultivation necessary for such crops in each zone. Cacao, cola, rubber and coffee belong to wet or Guinea zone, while cotton and shea butter nuts are suitable for the savannahs of the Sudanese zone or dry and medium zones.

Much cacao is grown on the Gold Coast in districts where the rainfall is insufficient or defective in distribution, but it appears able to survive, at any rate in more or less productive condition, owing to the high relative humidity of the air. Some years ago the cultivation of cacao in districts below 70 inches of rainfall well distributed would not have been attempted, but the meteorology of the districts concerned was unknown and farms were made. The cacao grown in such districts is, however, very badly affected by Sahlbergella (*see* Bulletin No. 3 of the Department of Agriculture), Thrips (*Heliothrips rubrocincta*) and Helopeltis (*Cacao mosquito*). It is doubtful whether, except under peasant cultivation, this crop would remain profitable.

Zones of Rainfall.

These are determined by taking the stations of equal average rainfall and drawing the isohyets or lines connecting such places. It is obvious that it would be impossible to show lines for every inch, and therefore the isohyets for every 5 inches are shown and the zones of equal rainfall lie between these lines. (*See* Plate XI).

The records from which these zones of rainfall are arrived at vary considerably in length of time over which observations have been made, and up to latitude 6° 30′ are based on a fairly large number of stations. In the Northern Territories and Togoland it has been difficult to establish a large number of stations owing to the lack of permanently resident observers, and therefore these lines are somewhat empirical. Their path is determined by calculation from surrounding stations. The fact that the records available produce an arrangement of zones comparable to what might be expected from the configuration of the surface of the country makes the assumption, that on general lines the system is correct, a very probable one.

The south-westerly moisture-laden monsoon blows during the wet season and therefore the south-west corner of the Colony has the greatest precipitation. The mountain range from Kumasi to Aburi naturally forms a block to the passage of this wind and compels it to deposit its moisture on the weather-side of the range. The whole of the area included by this range is of high rainfall

but it will be noticed that the area of greatest precipitation is around Axim. From this focus the contour lines radiate out in more or less concentric rings. Outside this area there are two distinct areas. One to the north and east where the clouds, now at much less saturation after passing over the mountain range, deposit comparatively little rain and therefore the area is of even distribution. The other is the coastal strip which lacks mountains and therefore offers no inducement to the clouds to deposit any moisture.

Rain-gauges.

The rain-gauges employed are the standard 8-inch gauge of Meteorological Office pattern and the records are taken in inches.

It is obvious that such records are incomplete in that they do not show any measurement of the rate of precipitation nor duration of rainfall.

The Hyetograph or mechanically recording rain-gauge shows not only the total fall but the rate and duration of the same. Unfortunately no such instrument is yet part of the equipment of stations in the Coast, nor is it desirable to have them except in the hands of qualified observers.

Rain-gauges must be set where no interference by houses or trees may take place, but even under the best conditions a certain amount of rain may be unrecorded due to splashing or by the wind blowing fiercely over the surface of the funnel. Driving rain is certainly not entirely trapped by rain-gauges.

The sudden gusty storms of the Gold Coast are possibly somewhat under-recorded and an investigation on this point is contemplated.

Effective Rainfall.

The total rainfall, especially in heavy storms, rarely becomes entirely available to the crops, and many factors influence the amount designated as effective rainfall.

Dade, in " The Economic Significance of Cacao-Pod Diseases " (Bulletin No. 6 of the Department of Agriculture), gives the effective rainfall as represented by a formula—

$$E = \frac{F}{P}$$

where E represents the " effect " of rain at any moment.
F represents the fall in inches.
P represents the period in days, including the day of fall, which has elapsed since the fall.

This, however, does not cover the factors detailed below :—

(1) Rate of precipitation.
(2) Interference.
(3) Run-off.
(4) Evaporation.
(5) Drainage.
(6) Type of soil.

(1) *Rate of Precipitation.*—Dade gives the following estimate of the value to be deducted from the total rainfall in the case of heavy precipitation :—

Over 5 in. in one day	60 %	deducted.
Between 4 in. to 5 in. in one day ..	50 %	,,
,, 3 in. to 4 in. ,, ..	33·3 %	,,
,, 2 in. to 3 in. ,, ..	25 %	,,

It is only empirical, but may be roughly correct on bare soil. It takes no account of a heavy fall of, say, 1 inch after which no more falls during the day. There are also other factors to be considered.

(2) *Interference.*—There may be forest scrub or grass on the soil which will prevent a varying percentage of the rain from reaching the soil at all. In the case of sudden storms followed by strong sunshine this trapped moisture will evaporate from the leaves of the plants.

This is particularly likely in the Gold Coast, and the total rainfall in the forest area must be certainly affected by this factor.

(3) *Run-off.*—On bare soils a loss, with heavy precipitation, is experienced by a proportion running off the bare surface to lower levels. This may reach drains or rivers and therefore not enter the soil at all.

This figure will vary with the amount of vegetation which may impede its progress, with the gradient of the soil surface, and with the drainage capacity of the soil.

(4) *Evaporation.*—On bare soils or areas lightly covered with vegetation a considerable amount of water is lost by evaporation. This evaporation has been proved to be heavy in tropical climates, and will vary according to the solar intensity. Several observers, using a free water surface, have found this to be as much as 95–105 per cent. of the total rainfall.

The evaporation from a free water-surface is certainly far greater than that from soil surface, owing to the fact of capillary lift from below being slow, and therefore the amount of moisture

available for evaporation is less over a given period of time. The crop is also drawing from this supply, and drainage is taking place to lower levels of soil, neither of which factors occur in evaporation tests from a free-water surface. The latter is merely an index of the solar intensity and maximum power of evaporation. This factor will vary according to the temperature, saturation deficit of the air and wind velocity and is more in evidence after the sudden storms of March and April than under the dull skies of the Gold Coast wet season.

(5) *Drainage.*—No figures are at present available for drainage capacity of Gold Coast soils, but it is hoped that drain-gauges will be installed in the near future. Figures from drain-gauges in temperate climates show that approximately 50 per cent. of the rainfall reaches the drains, and it is reasonable to suppose that this will be less in the Gold Coast, since the amount evaporated will be higher in proportion than in these temperate climates.

(6) *Type of Soil.*—On heavy soil which hardens readily during drought " run-off " will be considerably increased in amount. On soils of greater drainage capacity there will be a greater amount absorbed, and less will be lost by run-off and evaporation.

On very light soils more may be lost by drainage, but this is probably a slighter factor on the Gold Coast than the others by reason of the greater solar intensity.

Cultivated soils with a broken surface will also vary the conditions and ensure a greater absorption.

From these observations it appears that the actual amount of rainfall utilised by plants must be comparatively small, and experiments are in progress to try and estimate the value of each factor and the total loss of rainfall from each cause under varying conditions.

Duration of the effect of the varying quantities of rain under Gold Coast conditions is being also investigated, and the results will be published in due course.

Conservation of Moisture.

In countries with small rainfall or of low rainfall, when the amount lost from the causes shown above is deducted, it is necessary to use means to conserve what is possible for the use of plants and man.

The rainfall of the Gold Coast is not low when compared to that of the British Isles, but the evaporation-power of the sun is infinitely greater, and probably the run-off is also more in quantity owing to the rapid precipitation. It is low, however, when compared

with the majority of the West African Coast, and this is especially the case along the coastal strip in the Northern Territories and Togoland. When farms are being laid out in these districts it should be part of the cultivation to provide drains to catch the water across the slopes of the land to prevent run-off and soil erosion. (*See* Part VII).

Conservation of water also includes mulching the soil, use of green manures, and irrigation, which latter is the utilisation of the run-off water which has reached the streams. Such methods are discussed more fully under Meteorology and Agriculture (Part VII of this Bulletin).

Clouds.

It is impossible to deal adequately with clouds and cloud-formation in this Bulletin, as the variations need photographic illustration in order to demonstrate clearly the difference between the transitional types.

They are well set out, however, in the "Observers' Handbook" of the Meteorological Office, London.

The four primary types are—

(i.) Cirrus.
(ii.) Cumulus.
(iii.) Stratus.
(iv.) Nimbus.

Other types are intermediate in appearance between these primary types, and are derived during the transition from one primary to another. They are designated by such names as cirro-stratus, cirro-cumulus, etc.

(i.) *Cirrus*, or the mare's-tail cloud, is the highest cloud and reaches elevations of 30,000 feet or more. It is composed of ice-particles, and is often seen moving in a different direction to that shown by the clouds at lower altitudes. It moves so slowly, however, that a nephoscope is necessary to determine its movements. It is essentially a cloud of fine weather, and is frequently seen in the Gold Coast, especially during the dry season. It is, however, an indication of coming rain.

(ii.) *Cumulus*, or the wool-pack cloud, together with its varieties, alto-cumulus and fracto-cumulus, is the commonest cloud of all. It is a form found at 6,000 feet, and although usually a fine weather form, is easily convertible by physical features—such as hills, etc. —into cumulo-nimbus or storm cloud. On the other hand, it may rise of itself by evaporation of part of its moisture by sun heat or by wind influence and form alto-cumulus, a thicker variety of the

well-known "mackerel sky" (cirro-cumulus). This is usually at a height of 10,000 feet, and is very common in the evenings in the Gold Coast. Further evaporation and rise may give cirro-cumulus and later cirrus.

(iii.) *Stratus*, the early morning cloud at low levels, formed by condensation of the rising moisture due to the cooling of the lowest layer of air in contact with the earth's surface. Its further development depends on various factors. It may develop into fracto-stratus through alto-cumulus to cirrus or, if favourable conditions for further condensation are present, it may be converted at low levels into cumulus or nimbus according to the humidity of the atmosphere.

If the humidity is low the tendency is to lose water again to the sun-warmed atmosphere and rise to become alto-cumulus or alto-stratus, but if the humidity is high it fails to lose water, and will probably develop into nimbus and remain at low levels until the moisture is released as rain.

(iv.) *Nimbus*: the "rain cloud" or nimbus appears to be derived directly from cumulus through the transitional cumulo-nimbus or storm cloud when the conditions of the air are so moist that prolonged rain is necessary to maintain equilibrium.

It is, of course, a cloud of low altitude and practically only seen in this country during the months of May, June, July, September and October; the rains during March and April being derived from cumulo-nimbus, which is the cloud present during tornadoes.

In weather prediction and in the study of winds at varying heights the clouds give indications, by their movements and shape, of several points of interest in climatology. The direction of winds at varying altitudes may be studied, and also the probability of "weather" for twelve hours, by the variation in the cloud forms in conjunction with those winds. In the study of the incidence and character of tornadoes the only indication of the wind movements, except just at the commencement and finish of the storm, is given by the movements of the clouds. The writer, when watching the approach of a tornado in Togoland, noted clouds moving in two separate directions, both of which were across the path of the approaching storm.

PART VI.

CHANGES IN AIR PRESSURE AND VELOCITY.

The instruments concerned in recording the variation in air pressure and velocity are the barometer, barograph and anemometer.

Unfortunately Accra station alone possesses all these, while Kumasi has a barometer but neither barograph nor anemometer. It is therefore impossible to deal with such matters as areas of low pressure or areas of high pressure, called, in temperate climates, cyclones or anti-cyclones respectively. These give indications of the advance of wet and fine weather respectively.

One striking fact found in the records of the incidence of storms on the Gold Coast is the fact that before a storm arrives the barometer for two or three days steadily rises, sometimes three to four millibars, but a period of fine weather usually follows a depression, which is continued while the fine weather lasts.

The Barograph.

This instrument is a self-recording barometer, which gives the pressure at any one moment, and also variation in pressure, during the day. The diurnal variation at Accra is a standard curve and is shown in Plate VI. There is a rise in pressure from 6 a.m. to noon, reaching the maximum at 9 a.m. The corresponding depression occurs between noon and mid-day, reaching the minimum at about 5 p.m. A small peak occurs at 10.30 p.m. and a small depression at about 3 a.m. This variation is regular throughout the year and is rarely interrupted. In fact the characteristic diurnal variation is so consistent throughout the tropics that Von Humboldt has said that the time may be told by it.

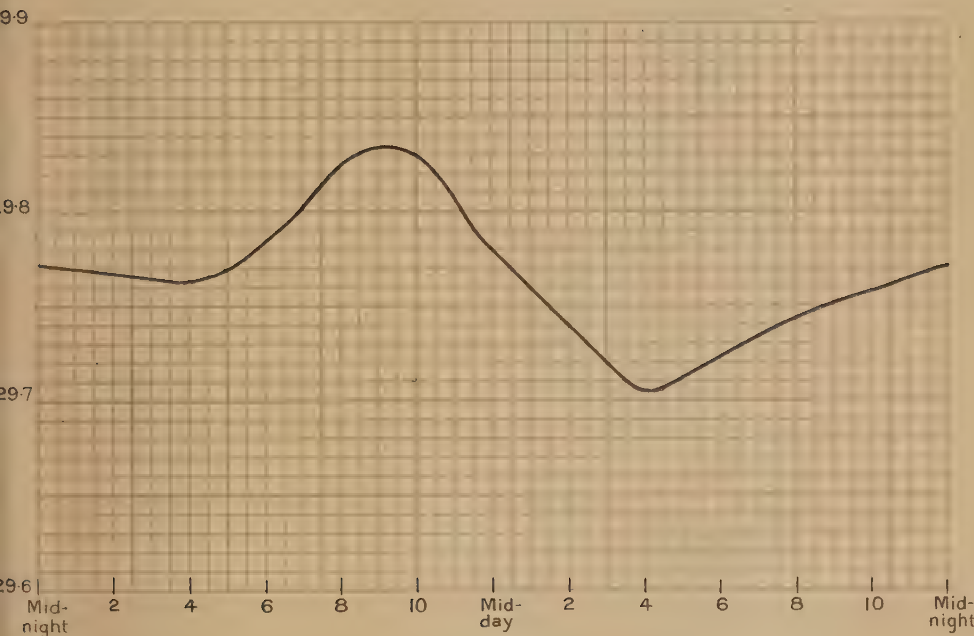
Tornadoes.

The word tornado is usually associated with the West African coast, and was originally applied to the storms, accompanied by squalls, which were experienced by navigators along the coast. They were considered to be similar to the hurricanes of the West Indies, the cyclones of North America, and typhoons of the East.

The term tornado means a thunderstorm, from the Spanish "tornado" and the Latin word "tonare," but was loosely believed to be derived from the Italian "tornare," to turn, in reference to the whirling eddies of wind accompanying it.

Such storms affect the barograph by first raising the pressure and then, as the centre passes over, a violent depression is recorded, with a corresponding rise as the storm passes. As the barograph

DAILY RANGE OF BAROMETER READINGS.



in Accra fails to record anything but minor indications of such phenomena, it is presumed that these storms are really precursors of tornadoes rather than true circular storms.

These storms do not develop the violent wind force of the hurricanes or the typhoons, and, although not sufficient evidence from anemometer readings is available, it appears that, in Accra, the speed of the wind rarely exceeds 40 miles per hour at the height of the storm. The highest actual reading has been only 47 miles per hour, on April 2nd, 1928.

Incidence of Tornadoes.

It is difficult, without a large number of stations, fitted with barometers, to trace the path of storms, and in this country there are only two barometric stations.

Tracing the path of storms has to be based therefore on the observations of prevailing winds, together with rainfall records.

In the latter section of this Bulletin on winds it is stated, from field observations, that the prevailing directions of the winds are north-east and south-west, and that these fit over one another in wedge formation.

The south-west monsoon is strong on the coast, and the north-east wind in the Northern Territories and the Sahara. Each of these becomes weaker when reaching the "focus" of the other, the north-eastern rising and the south-western keeping near the ground level.

It is assumed that the moist air moves from the sea towards the north until it reaches some point where it is compelled to rise. Such points are the Kumasi-Aburi hills and the Togoland range. Here it rises and, coming into the north-eastern wind zone, returns towards the sea as storms.

The storms which occur at intervals in Accra have been traced back to the Togoland range in this way.

Records show that storms originating in Kpeve district pass over Akuse and, passing east of Accra, go over the sea. Here apparently the clouds absorb moisture and drop to a lower level, where a south-east wind carries them over Accra. It is certain that the storms always approach from this quarter, but the origin of the south-east wind which brings them up is not yet explained.

They pass over the stations at Accra and Achimota and are next heard of at Oda, beyond which station there is no means of tracing them.

Oda is peculiar in that it gets not only tornadoes from the south-east but also from the north-east, which latter originate in the neighbourhood of the Mpraeso scarp and later pass over Cape Coast.

While admitting that this explanation of the path of storms is capable of discussion, and, in need of more accurate information, it is put forward in the hope that it may arouse interest and induce other observers to put forward alternatives based on their own observations.

The direction of winds for the greater part of the year in the Gold Coast is south-west, with slight variation. During the early part of the year the direction changes to north-east.

The south-west wind is known as the monsoon, derived from the Arabic word "mansim," meaning a season. It is moisture-laden, from passing over the Atlantic ocean, and gives rise to the wet season. The increase in southerly winds and corresponding decrease in northerly winds relative to the rains is well shown in the records for 1927 at Accra, in Table III.

The north-east wind is known as the harmattan, a word also derived from the Arabic, and blows from the Sahara desert, causing dry conditions and great range of temperature throughout the Colony. Hubert, in his "Mission Scientifique au Soudan," states that, from observations made in the field, he is of opinion that the harmattan blows throughout the year, but that, during the monsoon, it is confined to the upper levels of the air, and the monsoon inserts itself as a wedge between the harmattan and the ground surface.

This appears to be confirmed by the fact that the south-west monsoon is much less evident in the north than at the coast, and also from the fact that storms, as stated in the previous section, usually approach from the north-east.

When the sun passes towards the southern solstice the monsoon gradually lessens and finally ceases, due to greater heating of the area to the south of the coast and the corresponding rise of air-inducing currents from a northerly direction. There is a lessening of resistance to the harmattan, and this wind then drops to lower levels and takes the place of the monsoon. As the sun passes northward the monsoon arises again and the harmattan is forced up to the higher levels.

Table III shows the periodic rhythm of winds, taken from the wind records for Accra during 1927, tabulated together with the cloud-means (maximum 10), rainfall and rainy days, to show the correlation between the various observations. It will be noted that the predominant winds from November to February are northerly, and during the remainder of the year are southerly,

reaching the maximum in July. The variations which occur may be attributed to local breezes and eddies caused by clouds covering a part of the earth's surface and cooling it, and thereby making local currents of air. It must be remembered that the observations are made once daily, and that an average struck from the mean of hourly readings, or even twice daily, would show the persistence of the two periodic winds more clearly.

Force of Wind.

The force of the wind is recorded in Accra by an electrical recording cup anemometer of the Robinson pattern. It consists essentially of four cups, placed on 4-inch arms at right angles to one another on a top of a 30-feet mast. The pressure of wind in these cups rotates them on a spindle at the top which is connected with an ordinary bell battery below. When this battery is connected to the anemometer the completion of 25 revolutions rings the bell, and the time between the rings is averaged for several readings and the force of the wind read off on a calculated table.

At all other stations the speed of the wind is recorded by means of the Beaufort empirical scale, which records wind by its effect on moving the leaves or branches of trees and other objects.

Wind records at exceptional periods such as during a tornado or storm have been taken recently, but the speeds recorded have never exceeded 48 miles per hour. While it is certain that wind-speeds greater than this do occur, it is equally sure that the pace of the wind is not so great in Gold Coast as has been hitherto supposed.

The average wind speed in Accra is between 6 and 8 miles per hour, from records taken at 9 a.m., but this is nearly always exceeded during the afternoon, when the speed rises usually to 10 miles per hour.

The wind speed of the true cyclonic storm reaches 120 miles per hour, but as the anemometer is usually carried away at that speed, and it is certain that no speed approaching this has ever been recorded in the Gold Coast, it may be assumed that true cyclonic storms do not occur.

PART VII.

METEOROLOGY AND AGRICULTURE.

It is an evident fact that the agriculture of a country is dependent on the meteorological conditions obtaining in that country. There are optimum conditions for the growth and yield of crops dependent on factors such as temperature, moisture and sunshine, and it is useless or nearly so to attempt to grow plants outside the limits which these factors impose.

Typical crops of temperate climates are unsuitable for growth in tropical countries and *vice versa* without the aid of special appliances.

Variation in local conditions within the country will determine the areas available for the cultivation of various crops. In the Gold Coast the area of forest determines the economic limits of the growth of cacao, cola, oil-palm, etc.

The country around Sekondi is not a typical oil-palm district but, as will be seen in the rainfall contour map (Plate XI), the Axim district, a few miles to the west, has a very much higher rainfall and is entirely suitable. The cacao districts are also nearly entirely within the limits of the 55-inch rainfall contour.

The temperature of air and soil, which, in a temperate climate, are a determining factor, especially at their lower limits, are not of importance in the Gold Coast where the average temperature is always within the limits for all the crops concerned.

The Effect of Climate on Germination of Seed.

The germination of seed is dependent on the presence of air, a suitable temperature and moisture. The temperature of air and soil is always suitable in the Gold Coast and it depends on the farmer as to whether there is a supply of air in the soil by providing a satisfactory tilth of soil. The whole question of suitable conditions for germination then depends on the moisture and the main points are :—

(1) The sowing must take place in dry soil with a probability of rain in the future.

(2) The periods when excessive rain is likely is to be avoided since the tilth of the soil may be destroyed by the hammering action of the rain and subsequent baking by the sun. The seeds may also be washed out and any that are left in will very probably be smothered by the lack of air in the baked soil.

The optimum period for germination of seed appears to be after the tornado season in March and April and in early part of May when the rains are just commencing. In Accra there is usually a week of rain between May 1st and 10th, and therefore the last week in April appears to be the obvious sowing time.

The Effect of Climate on Cultivation Methods.

There are various cultivation methods which are dependent on the results of meteorological conditions of the district where they are applied.

In the Gold Coast these methods would be chiefly concerned with the conservation of moisture, since the other meteorological conditions do not effect the crops to any extent.

Such methods may be classified as under :—

1. Irrigation.
2. Mulching.
3. Green manuring.
4. Terracing.
5. Provision of shade.
6. Surface tillage.

Irrigation.—This is not practised at present in the Gold Coast but may become necessary in the future, owing to the constant deforestation which is taking place.

Irrigation could be the means of bringing into cultivation areas of the savannah district with insufficient rainfall but which are in proximity to large rivers. Such irrigation would be the means of conserving water which falls as rain on the other parts of the Colony and which finds its way by run-off or drainage into these rivers.

The question has been investigated in the Volta River district as a means of increasing the cotton growing area. The Volta reaches its highest levels in September and October, at which time the cotton would be requiring the moisture supplied by irrigation most.

Rice, in the Western Province, is probably a coming industry which might prove in need of irrigation. The present Government factory is at Essiama in the neighbourhood of the River Ancobra, which river might be utilised as a source of supply.

Mulching.—Cacao is often grown under insufficient shade and the desiccation of the soil by evaporation of water-supplies leads to smaller crops and attacks by insects such as Sahlbergella and Thrips. The plant is less able to resist the attacks, by fresh growth, and therefore much damage is done.

Covering the exposed soil by a mulch of grass or weeds which have been dug up, provided that these weeds have been killed before flowering, give a covering which will conserve any moisture in the soil for the use of crops.

Exact figures as to the increase of crop by mulching are not yet available, but the practice is common in other countries and must be made a standard method in districts where shade trees have been dispensed with.

Green Manuring.—This is a variation of mulching where annual crops are concerned. There may be a period between the reaping of a crop and the sowing of the next where a green crop such as peas or beans may be utilised as a cover crop to keep the soil covered and conserve the moisture. As an extension of this it may be desired to "rest" land between two crops in a rotation and during this period a cover crop is used and, in both cases, this crop is ploughed or dug in to return the plant foods to the soil.

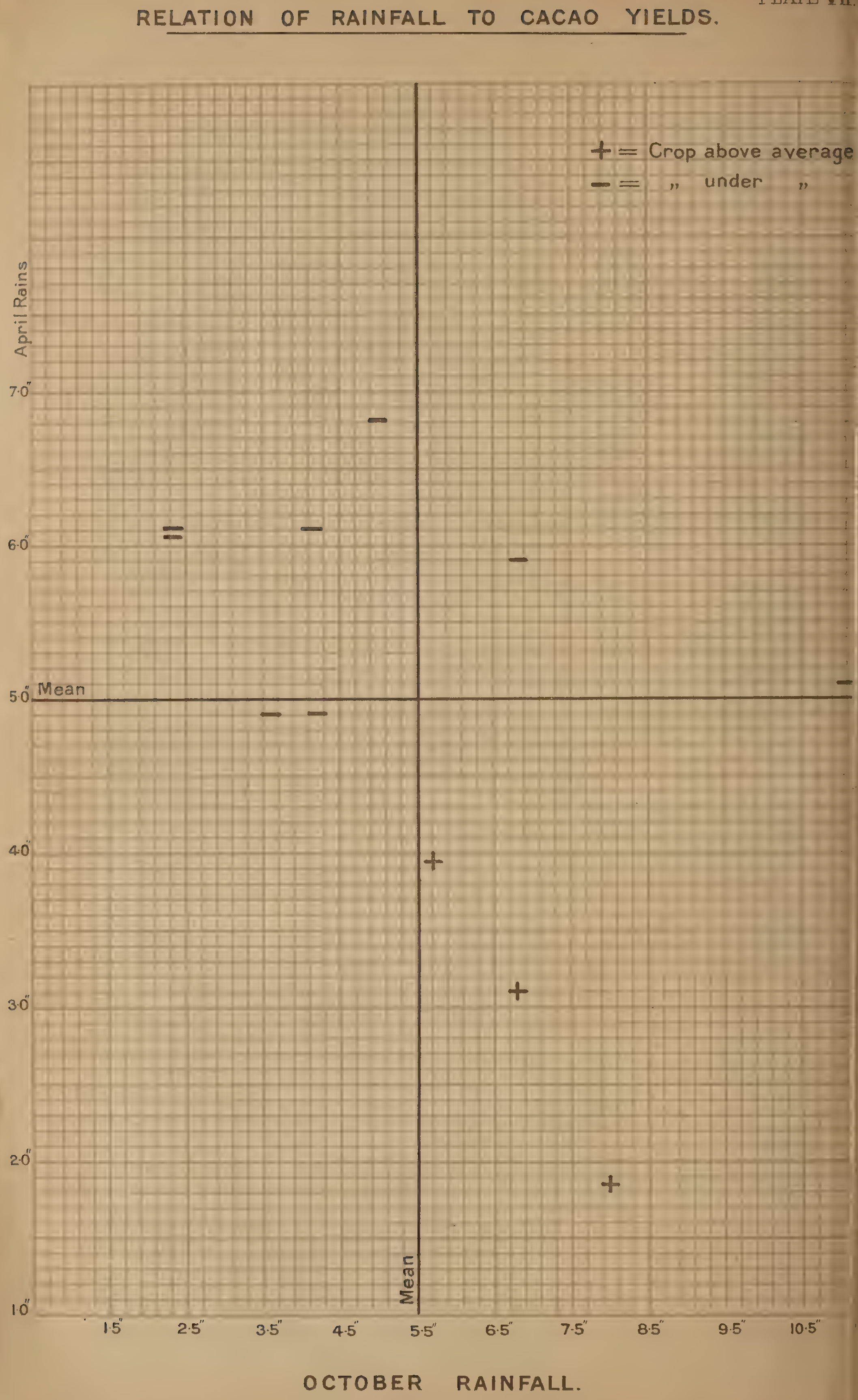
Terracing.—In districts where permanent crops are not grown and the soil is exposed to the sun's rays and to washing by rain during the cultivation of the annual crop, it is desirable, especially on farms in a fairly steep gradient, to prevent loss of moisture and soil-erosion by terracing. The terraces will be across the fall of the ground and will form an obstacle to the run-off when heavy precipitation occurs. In districts of light rainfall this could be carried further by the provision of contour-drains and the moisture collected be pumped up and used for watering. Such terracing is employed in the districts of Arabia where coffee is grown and in Ceylon where rice is similarly protected.

Provision of Shade.—When new farms are being made it is essential that not only should the forest trees be retained for high shade but that where necessary secondary shade in the shape of bananas, plantains, etc., be also employed to conserve moisture and to protect cacao, which is essentially a shade-loving plant. This is equally the case where food farms are being made which may ultimately be converted into cacao farms or farms carrying other crops.

Surface Tillage.—Before the farm becomes established and as an alternative to mulching it is possible to conserve soil-moisture by cultivation and keeping the surface-soil moved. So long as this is carried out the soil-moisture will only rise to the level of cultivation and evaporation at the surface will be lessened. The water will then be at root-level and the plants will be able to draw on the supplies without the competition of the evaporation by the heat of the sun.

It will be seen that these methods are chiefly concerned with districts where soil-erosion and evaporation of a limited rainfall occur. Such districts are found in the Gold Coast anywhere outside the limits of the 60-inch rainfall contour-line (*see* Plate IX). This

PLATE VII.


RELATION OF RAINFALL TO CACAO YIELDS.
+ = Crop above average
− = " under "
April Rains
7·0"
6·0"
5·0" Mean
4·0"
3·0"
2·0"
1·0"
Mean
1·5"
2·5"
3·5"
4·5"
5·5"
6·5"
7·5"
8·5"
9·5"
10·5"
OCTOBER RAINFALL.

comprises a very large area of the Colony, Ashanti, Northern Territories and Togoland, and therefore it has been considered worth while to give so much attention to it. Actual details of the cultivation are outside the scope of the present Bulletin and therefore only the reasons for such work have been given.

On taking over a farm or on breaking up new land a knowledge of the meteorological conditions to be expected will give the prospective farmer an indication as to the expenditure likely to be necessary on cultivation of this kind.

Correlation of Crop Yields and Meteorological Conditions.

This very important section of applied meteorology is as yet in its infancy in the Gold Coast largely because the records of crop yields and meteorological factors do not cover a sufficient number of years in the majority of cases.

Maidment, in the Department of Agriculture Year Book, 1927, opened the subject by a correlation of the yield of cacao with the rainfall on three Agricultural Experiment Stations.

He points out that a low rainfall in April causes a cessation of vegetative growth and a consequent production of flowers. The consequent yield will be in direct relation to this provided other factors do not interfere. A dry period following flowering would, of course, interfere with setting of fruit.

The graphs illustrating this paper are somewhat unwieldy and therefore a spot graph on the American method of crop-prediction has been prepared to show the relation in a more evident form (*see* Plate VII).

These graphs are prepared by taking two factors, in this case the April rainfall and the previous October rainfall, which affect the main season and mid-season respectively. The means of these factors are taken as ordinates and the actual readings for any one year determine the position of the crop for that year. Whether the crop is above or below the average is designated by a plus or minus sign at the point of intersection. By this means the probability of a plus or minus crop expected from the rainfall reading is determined, and it is seen by the charts that given dry conditions at the critical periods, the chances are that the crop will be above the average. The reverse will usually be the case when the rainfall in these periods is above the average.

Further correlation of this kind on all sorts of crops and in all parts of the country will enable the Department to predict with a reasonable amount of certainty, as is done in America, what crop may be expected in total and also what parts of the country will carry a heavier or lighter crop than usual.

It is obvious that the critical periods for each crop will not be the same and that a study to get this period designated is the first step.

Phenology.

It has been shown above that it is possible to obtain an idea as to the amount of a crop by means of correlation. Phenology or the study of the relation between climate and periodic biologic phenomena gives an idea of the earliness or lateness of the season.

It is usual to take a certain number of uncultivated plants of varying species and to note dates on which the specimens selected commence new growth, flower or fruit. These dates are compared yearly and an estimate made as to the dates when crops may be expected to commence yielding.

So far such study has not been attempted in the Gold Coast but, as it is of importance in crop prediction to have such records, it is proposed to start at once by selecting suitable species and in a few years the records will have a distinct value.

Sun-drying of Cacao.

On the Gold Coast cacao is entirely dried by exposure to the sun's rays. Such a method is dependent on having sunlight and no rain when the cacao crop is being collected. Without this much labour has to be expended in collecting the exposed beans on the advance of a storm and in re-spreading after the storm has passed.

Certain areas, which are said to produce bad cacao can be seen, on referring to Table IV, to be sufferers by an excessive number of rainy days at the time when drying is being carried out. Such areas are found chiefly in the Western Province and it is a matter of importance to the industry to see whether it would be advantageous to employ artificial drying in areas which have an excessive number of wet days during that period (*see* Table IV).

From the discussion of the above points it will be seen that the meteorological and climatic factors have a very distinct bearing on the agriculture of the Colony and that accurate records are very valuable to the elucidation of various problems.

It may also be mentioned that records are valuable to other departments whose activities demand knowledge of this sort, especially in relation to rainfall.

N. P. CHAMNEY,

Officer-in-Charge,

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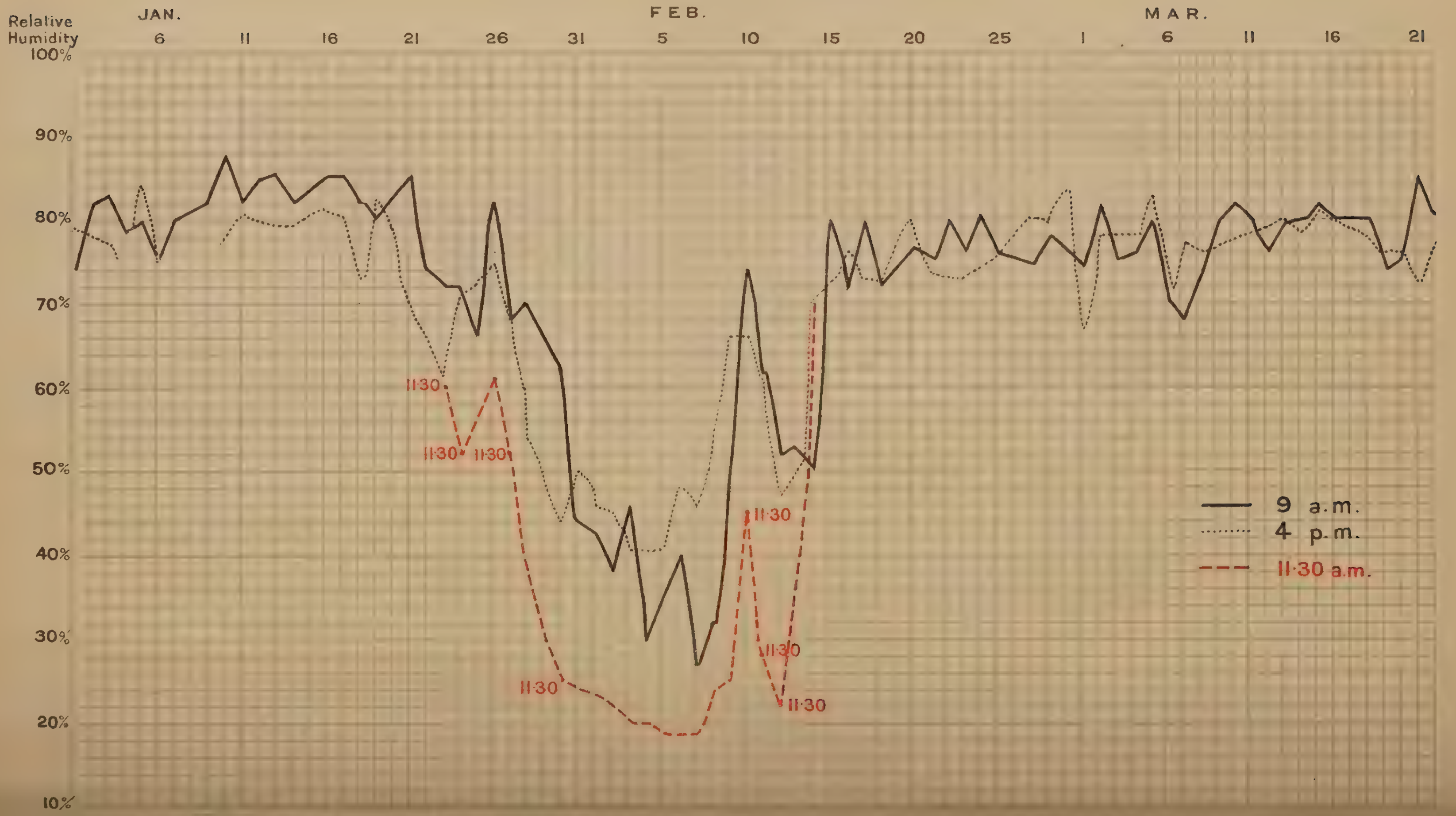
RELATIVE HUMIDITY READINGS DURING HARMATTAN.

ACCRA 1928.



APPENDIX A.

THE HARMATTAN SEASON.

The Harmattan season of West Africa is a moveable period which occurs during the early months of the year. When the sun moves towards the southern solstice the south-west monsoon which blows for the majority of the year ceases. This may be due to the sun being vertical over a portion of the globe to the south of the Gold Coast and the attraction of the winds being towards the area of greatest heat. Hot air rises and the colder air from the north of the Tropic of Cancer moves towards it thereby causing a cessation of the south-west monsoon. The north-east wind which has been blowing at high levels throughout the year then drops to take its place and coming from the Sahara is exceedingly dry.

The phenomena experienced during this season are a lowering of humidity, hot days with cold nights and dusty haze caused by the red dust of the Sahara desert being carried and deposited over the Colony.

Humidity.

The characteristic drop in humidity is very evident to ordinary tests. Every book and paper curls up and the skin feels parched and dry; in extreme cases a "chapping" and peeling of the lips is experienced.

The relative humidity (*see* Plate IV) drops very rapidly, as much as 43 per cent. in one day having been recorded in Accra and 57 per cent. in one at Kintampo.

This drop persists throughout the harmattan season with minor fluctuations and although the normal humidity is in the neighbourhood of 85 per cent., a varying figure of from 25 per cent. to 50 per cent. is recorded daily during the prevalence of the north-east wind.

The desiccation of the skin is very trying especially to newcomers to the Coast, and the extremes of temperature are liable to cause an epidemic of "colds."

Temperature.

The temperatures recorded during this period are usually extreme. The difference between the shade maximum and minimum becomes abnormally wide and it is usually accompanied by cold nights.

Duration.

The duration of the harmattan varies with the district very considerably. According to the records of the direction of the wind and the relative humidity this "season" lasts from three months in the extreme north of the Northern Territories to a maximum of twenty days on the coast. The south-west corner of the coastal strip does not appear to exhibit any of the characteristic records which are associated with the harmattan in other districts. Asuansi, Sekondi and Axim do not get a lower relative humidity than 50 per cent., whereas Tamale, Kintampo, Accra, Akuse and Aburi all show a humidity of 30 per cent. or under.

It appears that, although the harmattan decreases in duration when reaching the coastal strip, yet it does not decrease in intensity except where it passes over the forest country. The eastern side of savannah country in Togoland over which the north-east wind must blow to reach Aburi, Accra and Akuse does not give up any moisture and the desiccation is the same at the coast as in the north. When, however, the stations under observation have an area of wet humid forest between them and the wind origin there is a gathering of humidity during the passage of the harmattan over the forest and the effect is not so marked at the coast.

Seasonal Variation.

The harmattan varies considerably as to its date of commencement. In Accra, for instance, it commenced in 1926 on January 1st, in 1927 on January 8th, and in 1928 on January 29th. It was most severe in 1927, although in 1928 it was of longer duration, and the severity spread over a longer period. The charts drawn to show the readings of relative humidity for Accra during the last three harmattan seasons illustrated the above points well.

The Effect on Crops.

The desiccating effect of the north-east wind causes defoliation of trees and plants in order that less transpiration of the water supply may take place. No rain falls during the period and the plants have to conserve all the moisture possible. Hence if the north-east wind persists for a long time a serious check to crop is experienced and a loss of crop or a late ripening is the result. The damage may, in the case of perrenial crops, be a permanent one.

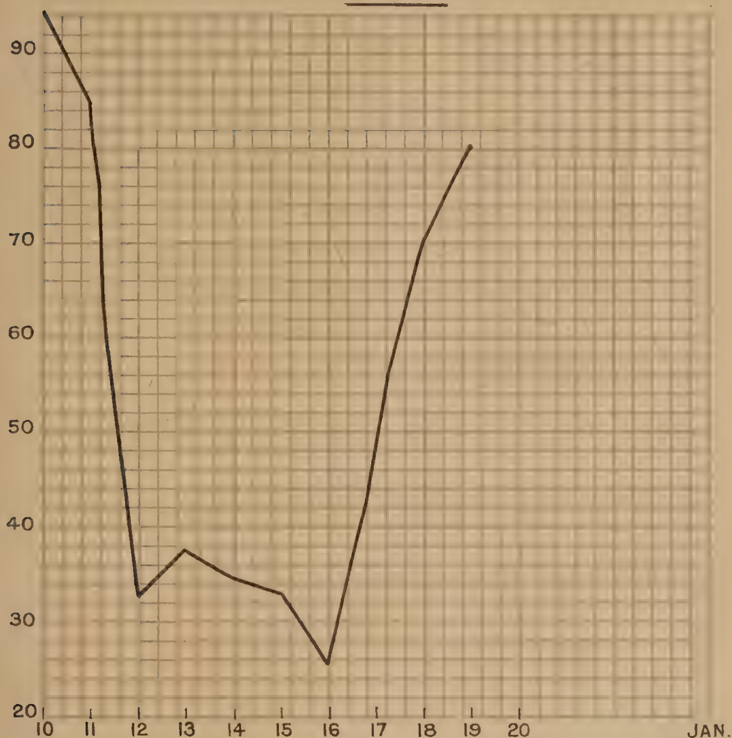
Varying Humidity during Day.

Mr. R. Simmons, Analytical Chemist, Medical Department, has communicated his observations on the changes in relative humidity during the day in the harmattan season.

HARMATTAN 1927.

Diminution of Relative Humidity of the Atmosphere.

ABURI.



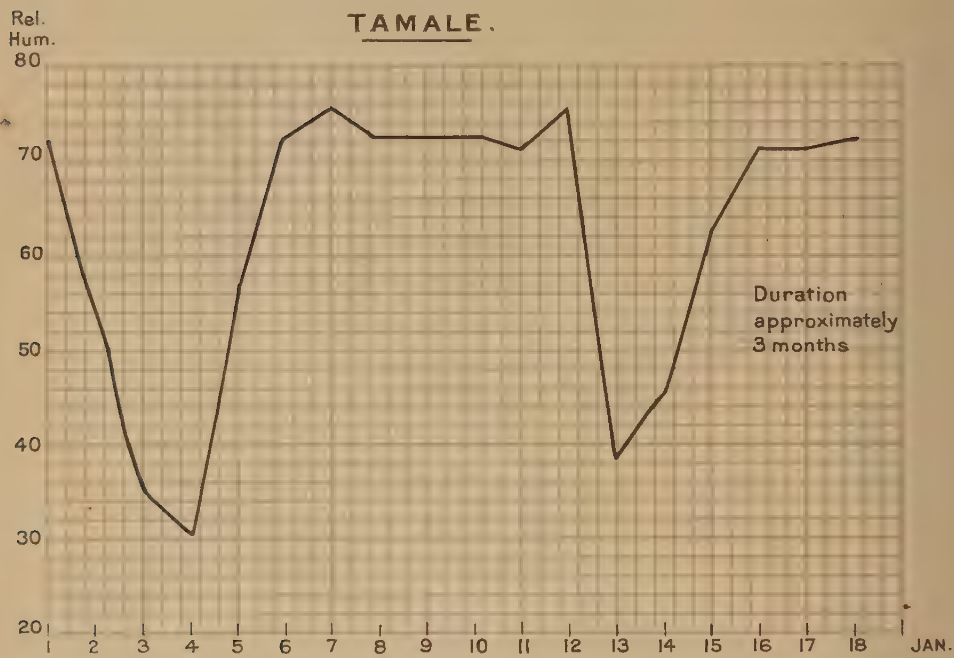
KUMASI.

PLATE X.

HARMATTAN 1927.

Diminution of Relative Humidity of the Atmosphere.

TAMALE.



These observations were made at the Analytical Laboratory in Accra distant about half-mile from the Meteorological Station.

He observed the humidity three times daily—at 9 a.m., 11 a.m. and 4 p.m. The greatest amount of desiccation was observed at 11 a.m. and the least at 4 p.m. The curve for 11 a.m. shows the minimum humidity at 18 per cent. which is exceedingly low and indicate plainly the excessive dryness of the air at this period. A chart illustrating these figures appears as Plate VIII.

Variation in Thermograph Charts.

During the harmattan it is noticeable that the ordinary diurnal fluctuations in temperature undergo a distinct change. The diurnal range, which is normally 10° becomes 20° or over and a sharp peak occurs at the maximum reading. The normal curve reaches its highest point at 3 p.m., whereas during the season under consideration this peak occurs from mid-day to one o'clock. During 1927 it was noticed that there was a distinct break in the severity of the harmattan on February 5th and 6th, and during these two days the curve shown by the thermograph returned more or less to the normal shape.

APPENDIX B.

"TIRING OF THERMOMETERS."

While re-tabulating the meteorological records of the Colony the writer noticed a diminution, in the readings of certain types of thermometers, which was definitely progressive and this occurred notably in thermometers exposed to the sun's rays, viz., the solar radiation and grass minimum thermometer.

The records were then carefully searched and many cases were found. Some of these were apparently due to instruments defective in the first case or obviously imperfectly read and were therefore discarded. A case in point was at Keta where a new instrument gave imperfect records from the start and was discarded in six months. This was probably due to the column of alcohol, which might have been broken in transit, not being corrected before the instrument was set up.

For the purposes of this paper nine records have been taken (*see* Table V), where thermometers recording accurately for a period of one to three years, have given readings which have decreased by an average figure of 10° per annum over a varying period before a new instrument has been supplied. The new instrument in each case has immediately given greatly increased readings but in certain cases has itself deteriorated with time.

Probable Causes of the Error.

Several theories may be advanced to explain this phenomenon, all of which may be contributory, but it is more likely that one of these is the main factor if not the entire cause.

(1) *Inaccurate observation.*—This may be the cause of the error entirely owing to a break in the column of the indicator. As however, in certain cases this consists of mercury and in others alcohol, it seems unlikely that this factor is entirely responsible. Breaks in alcohol columns are common and equally easy to correct and all observers are instructed in the method of correction. It seems unlikely that this would be allowed to proceed over a period of years. Mercury is not so easily "broken" and the Solar Radiation thermometers under observation in Accra have never suffered from this error.

Observers would most certainly have reported this at once especially in the case of mercurial thermometers, where such breaks in the column are readily observable.

(2) *Evaporation and Recondensation.*—When thermometers are exposed to direct sunlight of tropical intensity, it is certainly possible that, in the case of alcohol columns, evaporation of the alcohol and a recondensation during the night at varying heights in the tube might take place. In the case of mercury, with a comparatively high vaporisation-point, this is hardly likely to take place and equal cases of inaccuracy are found in both classes.

(3) *Evaporation or Chemical Action.*—In the case of alcohol thermometers it is just possible that evaporation through the glass may take place, as it is well known that liquid can pass through glass under certain conditions of temperature and pressure. This is very unlikely to occur in the comparatively small variations of temperature and pressure to which the instruments are submitted.

W. F. Higgins, M.Sc., found that alcohol thermometers in which the spirit contained 1 per cent. of acetone had a rate of fall of 1° F. per month. Although this is in excess of what is observed in this case it is very probably the explanation and that the variation in rate of diminution observed varies as the percentage of acetone in the spirit employed.

In the case of mercury, a compound known as mercury-glass is known to exist, but here again it seems unlikely that this would be formed under the existing conditions.

(4) *Alteration of the Surface-tension.*—The thermometer is dependent to a certain extent on the surface-tension existing between the recording column and the walls of the tube. When a thermometer is constructed, these walls are smooth and the column runs freely up and down. During the period of observation (say four years) there is a possibility that the constant daily expansion and contraction of the tubing causes what is known as "tiring" (in the case of steel), that is to say a definite alteration of the molecular density of the glass and also possibly a crystallisation. This would affect the thermometer by causing possibly a roughening of the inside surface of the tube and a consequent greater resistance to the passage of the column of mercury or alcohol which would result in lower readings. It is not probable that such a factor would alone account for the phenomenon.

(5) *Increase in Size of Tube.*—As mentioned above a "tiring" of the glass may result in a difference in molecular density of the glass and a constant increase in diameter of the tube and bulb due to loss of elasticity during the constant daily expansion and contraction. The well-known increase in length of rubber tubing after incessant expansion and contraction illustrates this point. The tube of the thermometer being fixed at each end may expand in diameter and thus give gradually increasing lower readings. The large co-efficient of expansion of alcohol relative to that of glass renders this unlikely.

(6) *Deterioration of Vacuum.*—In the case of the Solar maximum thermometers the probable cause is deterioration of the vacuum, causing conduction of heat away from the bulb coupled with a falling off of the coating of lamp-black, which would impair the power of absorption of the bulb.

Conclusions.—Investigational work is necessary to clear up this point and to get definite information. What is needed is a duplicate set of instruments at each station in order that, firstly, there be no break in the sequence of records such as would be the case when instruments have to be supplied from Accra, and secondly, in order that an occasional test may be made by recording from any pair of thermometers at the same time, and consequent checking of records.

It is suggested that checking of this kind should be always done at Accra under efficient supervision to determine the life of the thermometer on the Coast, and that duplicate instruments be added at intervals of twelve months to ensure that the standard instruments are not losing their efficiency.

Weight determinations might be tried to see if there is any variation in the dry weight of instruments indicating an actual loss by evaporation, although since each instrument is enclosed in an outer tube this is unlikely.

Although it is only instruments exposed to the sun's rays that are noticeably affected it would be advisable that similar checks be employed on the shade thermometers, and for this reason a plan of a station to be set up at headquarters to allow "batteries" of instruments of each sort to be tested regularly under efficient supervision is being devised, and is recommended to be a feature of the meteorological station at headquarters.

It must be remembered that these thermometers are made in temperate climates and tested in temperate climates, and that although they undergo a test under extreme conditions at the National Physical Laboratory, they do not undergo the prolonged test of exposure to tropical conditions.

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TABLE II.

DISTRIBUTION OF RECORDING STATIONS.

Meteorological Stations.	Rainfall Stations.		
1. *Coastal Savannah.*			
Accra.	Labadi.		
Ada*.	Abra.		
Keta.	Ajua		
Sekondi.	Angu.		
Cape Coast.	Butre.		
Winnebah.*	Inchaban.*		
Saltpond.*	Mansu.		
Achimota.†	Mpenassa.		
2. *Forest Area.*			
Tarkwa.	Abetifi.†	Asamankese.	Effiduase.
Kumasi.	Abompasu.	Asromaso.	Ejisu.
Asuansi.	Adeja.†	Anyinasu.*	Esuasu.
Begoro.	Adebrem.	Bekwai.	Goaso.
Aburi.	Agona.	Birimsu.*	Hemang.
Axim.	Akropong.	Bunso.	Jema.*
	Akwantambra.*	Dentin.†	Juaso.
	Anyinam.	Dunkwa.	Kibi.
	Wiaso.	Tafo.	Kodeakese.
	Atwabo.	Tikrom.	Sukusuku.*
	Koforidua.	Half Assini.	Oda.
	Mpirim.	Nkwatia.*	Siwum.
	Nkawkaw.	Obuasi.	
3. *Transitional.*			
Sunyani.*	Ejura.		
Kintampo.	Mampong.		
Kpeve.	Wenchi.		
	Odumasi.		
	Peki-Blengo.		
	Nsawam.		
4. *Parkland.*			
Tamlae.	Bole.†		
Gambaga* Rainfall	Kete Kratchi.		
Ho* only now.	Kpetsu.*		
Akuse.	Labolabo.*		
	Navrongo.		
	Salaga.		
	Senchi.*		
	Wa.		
	Yendi.		
	Zuarungu.		

* Closed. † Recently opened and therefore records not included.

TABLE III.

WIND RECORDS FOR ACCRA, 1927.

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Clouds Mean	Rain in inches	Wet Days.
January ..	9	5	1	2	—	1	5	8	2·3	·50	2
February	2	3	1	—	—	5	11	5	5·4	3·87	4
March ..	4	—	—	—	—	13	4	9	4·9	1·88	4
April ..	1	1	—	—	2	11	—	15	6·0	1·40	5
May ..	2	1	—	—	—	17	1	5	5·9	6·60	8
June ..	—	2	—	—	—	23	—	3	7·0	2·10	8
July ..	—	—	—	—	—	31	—	—	7·2	·39	4
August ..	—	—	—	—	—	29	—	2	7·3	·04	1
September	—	—	—	—	—	26	2	2	7·2	·13	4
October ..	1	2	—	3	—	13	3	9	6·5	1·48	9
November	1	3	—	—	—	8	4	14	4·5	1·16	5
December	1	6	—	—	—	4	5	14	4·7	5·29	6

TABLE IV.

AVERAGE NUMBER OF WET DAYS DURING CACAO DRYING SEASON

Station.	September	October	November	December	Total.
Abompasu	21	21	15	5	62
Tarkwa	16	19	15	8	58
Oda	15	17	16	6	53
Kibi	15	18	13	7	53
Mpraeso	19	17	9	4	49
Goaso	17	19	10	2	48
Juaso	16	17	9	5	47
Dunkwa	15	16	11	3	45
Asuansi	15	13	9	7	44
Hemang	13	14	11	5	43
Nkawkaw	13	17	9	4	43
Tafo	12	17	8	5	42
Wenchi	15	17	8	1	41
Kumasi	13	15	9	3	40
Asamankese	12	11	10	6	39
Koforidua	11	13	10	5	39
Sunyani	15	15	8	1	39
Aburi	11	12	10	6	39
Wiawso	13	12	9	3	37
Bekwai	11	13	10	3	36
Peki-Blengo	10	12	8	3	33
Anyinam	10	11	6	3	30
Nsawam	7	10	7	5	29

TABLE V.

RECORDS SHOWING TIRING OF THERMOMETERS.

(A) MINIMUM TERRESTRIAL.

	Accra.			Axim.	
	1915	1916	1917	1923	1924
January	73·9	55·1	*67·1	61·7	47·0
February	73·1	67·7	69·1	58·5	45·9
March	70·7	69·9	—	58·5	45·7
April	69·7	65·3	—	56·7	43·2
May	62·5	52·7	—	55·9	40·7
June	68·2	58·0	—	54·6	39·8
July	70·9	47·3	—	53·2	37·8
August	67·2	49·1	—	51·8	36·2
September	68·9	45·6	—	48·2	37·3
October	62·5	40·4	—	47·0	—
November	57·9	40·9	—	45·9	*64·2
December	56·5	39·7	—	45·8	67·9

* New Instrument.

	Sunyani.			Keta.	
	1913	1914	1915	1923	1924
January	49·74	52·8	—	70·6	40·6
February	54·92	57·2	—	70·9	41·1
March	55·52	60·5	*72·12	69·4	40·8
April	57·10	59·3	72·23	64·5	41·2
May	53·90	—	70·83	53·8	36·3
June	56·70	—	—	48·8	26·8
July	55·5	—	—	44·3	22·5
August	56·4	—	—	41·5	20·3
September	55·4	—	—	40·6	—
October	57·4	—	—	44·3	—
November	57·6	—	—	41·9	—
December	55·2	—	—	40·7	*70·6

* New Instrument.

	Sekondi.	
	1921	1922
January	74·6	37·1
February	73·0	45·8
March	72·7	49·9
April	71·4	49·1
May	60·4	42·7
June	52·0	43·3
July	51·4	*69·1
August	54·4	70·9
September	58·1	69·9
October	56·1	70·8
November	53·7	71·4
December	49·1	72·2

* New Instrument.

TABLE V. (*contd.*).

(B) SOLAR MAXIMUM.

	Keta.			Axim.			
	1914	1915	1916	1917	1918	1919	1920
January ..	134·3	121·6	—	132·1	—	91·9	99·0
February ..	143·1	118·7	—	129·2	95·8	95·8	97·7
March	146·6	126·6	—	132·6	98·3	94·0	97·8
April	132·2	118·6	—	118·9	102·4	99·7	95·8
May	147·3	121·1	*156·7	108·8	95·9	95·4	91·0
June	131·1	113·2	149·7	110·3	94·4	93·6	95·9
July	128·7	105·8	150·1	92·5	91·5	94·1	87·6
August ..	138·5	103·2	—	97·7	97·9	92·2	91·8
September ..	142·4	112·8	—	102·2	88·5	91·6	95·3
October ..	142·5	122·3	—	107·4	91·2	91·0	—
November ..	142·9	—	—	113·0	93·5	99·3	*157·9
December ..	142·2	—	—	116·5	91·3	96·3	165·6

* New instrument.

	Aburi.		
	1925	1926	1927
January ..	140·0	134·9	128·4
February ..	150·4	139·8	125·7
March	154·6	143·9	125·2
April	153·2	141·6	125·8
May	156·0	137·8	123·8
June	141·6	131·3	118·3
July	142·1	126·8	105·0
August	142·8	117·5	107·9
September ..	142·2	130·8	103·7
October ..	154·9	133·6	115·0
November ..	143·4	132·4	117·9
December ..	156·4	136·4	117·9

TABLE VI.

MEAN ANNUAL RECORDS.

Station.	Shade Maxi-mum Mean.	Shade Minimum Mean.	Mean Annual Range.	Mean Relative Humi-dity.	Mean Solar Maxi-mum.	Mean Grass Mini-mum.	Station closed since
Accra (25)	85·2	73·6	11·5	73·4	144·9	74·5	—
Aburi (25)	85·6	69·3	16·3	85·7	139·2	61·9	—
Begoro (5)	86·4	67·3	19·1	82·2	—	—	—
Akuse (7)	93·2	69·2	24·0	72·5	148·4	63·0	—
Keta (15)	86·9	74·6	12·3	72·1	145·4	62·4	—
Asuansi (7)	85·4	70·5	14·9	85·9	—	68·8	—
Sekondi (15)	87·0	73·1	13·9	80·7	139·4	67·5	—
Axim (15)	83·6	71·0	12·6	88·0	117·8	64·4	—
Tarkwa (15)	89·5	70·5	19·0	85·4	145·3	69·6	—
Kumasi (15)	88·1	70·2	17·9	84·2	134·5	69·4	—
Kintampo (15)	88·2	68·9	19·3	71·2	138·0	67·5	—
Tamale (15)	94·0	69·4	24·6	61·2	147·7	63·1	—
Ada (8)	86·5	75·3	11·2	82·2	143·9	71·6	1921
Cape Coast (7)	84·8	69·1	15·7	79·7	140·9	66·0	1920
Sunyani (8)	90·4	64·4	26·0	79·6	136·6	65·7	1921
Gambaga (8)	92·8	70·9	21·9	69·1	150·9	69·2	1921
Winneba (5)	84·7	71·9	12·8	82·2	143·7	63·4	1921
Saltpond (5)	83·9	71·3	12·6	80·6	126·5	70·3	1921
Ho (6)	90·8	71·7	19·1	86·8	140·0	62·7	1927

TABLE VII.

SHADE MAXIMUM TEMPERATURE.

Month.	Tamale.	Akuse.	Gambaga.	Ho.	Sunyani.	Tarkwa.	Kintampo.	Kumasi.	Sekondi.	Keta.
January ..	96·34	94·95	93·83	93·96	92·75	89·11	87·80	89·67	88·67	87·40
February ..	99·54	97·81	96·93	96·57	94·94	93·09	91·46	92·62	89·81	89·03
March ..	100·82	96·39	99·15	95·45	94·76	93·47	91·96	91·62	90·52	88·40
April ..	98·22	95.86	97·45	92·95	93·74	92·56	88·18	89·91	90·04	87·07
May ..	95·56	96·32	94·58	91·13	92·10	91·57	89·46	90·38	89·08	87·75
June ..	91·62	90·14	91·79	86·73	88·34	87·44	86·70	86·23	85·56	87·82
July ..	86·46	87·95	86·93	84·57	85·57	86·41	85·28	82·86	83·69	86·30
August ..	87·29	91·92	87·39	86·47	84·21	84·75	84·36	82·19	82·70	84·49
September ..	87·11	89·74	89·93	87·01	87·93	85·59	84·46	84·68	83·82	84·74
October ..	91·58	92·51	90·83	90·01	90·56	89·14	81·84	88·02	85·96	86·04
November ..	95·54	94·38	90·46	91·68	90·72	91·26	90·68	89·73	88·37	84·16
December ..	97·34	95·96	96·24	93·45	88·85	88·45	90·64	89·68	88·79	87·65
Mean ..	93·95	93·20	92·79	90·83	90·37	89·45	88·23	88·09	87·01	86·89

Month.	Ada.	Begoro.	Aburi.	Asuansi.	Accra.	Cape Coast.	Winneba.	Saltpond.	Axim.	
January ..	87·07	89·20	89·18	86·69	88·2	86·04	86·75	86·10	84·87	..
February ..	89·51	91·05	90·40	89·34	88·2	87·56	87·30	86·75	85·73	..
March ..	88·74	91·03	89·27	88·95	88·2	89·20	88·85	86·61	85·68	..
April ..	88·53	88·82	88·89	88·26	87·9	88·30	86·32	85·36	85·18	..
May ..	86·50	90·33	87·54	87·14	86·7	86·68	85·59	84·33	84·32	..
June ..	86·19	84·95	84·12	83·03	83·9	82·73	83·27	82·31	81·74	..
July ..	85·27	82·26	80·66	81·38	81·3	80·89	80·49	81·34	80·99	..
August ..	84·85	80·84	81·32	80·97	80·0	80·30	79·58	79·63	80·29	..
September ..	85·17	84·18	82·61	81·58	81·1	82·10	81·16	79·72	80·48	..
October ..	82·51	85·17	84·62	84·30	82·5	84·93	83·95	84·61	81·23	..
November ..	86·45	86·92	85·61	86·16	86·8	83·43	86·37	84·16	83·94	..
December ..	87·43	88·26	85·82	86·37	88·1	85·60	86·30	86·33	85·19	..
Mean ..	86·52	86·40	85·6	85·45	85·2	84·81	84·66	83·94	83·58	..

TABLE VIII.

SHADE MINIMUM TEMPERATURE.

Month.	Ada.	Keta.	Accra.	Sekondi.	Winneba.	Ho.	Saltpond.	Axim.	Gambaga.	Asuansi.
January ..	76·06	70·62	72·9	75·42	70·74	71·76	72·30	70·46	69·93	68·31
February ..	75·79	73·32	73·2	73·97	71·69	73·86	72·69	73·58	72·03	70·97
March ..	76·18	75·95	75·0	74·53	72·94	73·85	73·09	72·57	72·89	71·45
April ..	75·50	75·59	74·3	74·02	73·54	73·42	72·73	71·90	72·50	71·58
May ..	74·07	77·57	73·8	74·74	73·04	72·15	72·40	72·07	71·36	71·76
June ..	74·98	77·51	73·5	75·94	72·60	70·81	72·05	71·14	70·91	71·31
July ..	74·90	76·04	72·5	73·92	71·44	69·93	70·98	70·99	69·85	70·00
August ..	74·41	74·55	71·6	70·89	68·22	69·43	69·42	69·59	69·66	69·51
September ..	75·32	91·56	72·8	71·48	71·46	70·33	69·94	69·11	69·96	70·89
October ..	74·92	71·47	73·1	72·33	72·75	70·58	69·40	68·32	70·56	70·65
November ..	75·31	73·49	73·5	72·96	72·37	72·33	69·65	70·60	70·54	70·20
December ..	75·74	72·14	74·5	73·37	71·84	72·47	70·72	71·67	71·14	69·97
Mean ..	75·26	74·63	73·6	73·11	71·89	71·74	71·28	71·00	70·94	70·53

Month.	Tarkwa.	Kumasi.	Tamale.	Aburi.	Akuse.	Cape Coast.	Kintampo.	Begoro.	Sunyani.	
January ..	68·11	66·05	65·40	69·03	67·59	70·36	65·74	65·5	58·72	..
February ..	71·66	71·05	69·90	71·04	71·85	71·08	69·22	66·1	61·84	..
March ..	71·42	71·15	73·90	71·61	72·80	68·70	70·84	67·3	66·61	..
April ..	71·68	71·26	72·13	70·72	72·38	68·39	70·62	66·6	66·50	..
May ..	71·79	71·25	72·54	71·64	71·81	67·39	70·22	67·6	66·82	..
June ..	70·41	70·91	69·06	69·64	69·27	70·69	69·20	68·7	66·17	..
July ..	69·18	69·73	69·95	67·95	67·87	70·59	68·85	67·1	65·23	..
August ..	68·85	69·37	67·55	66·94	66·59	65·53	68·22	67·0	63·45	..
September ..	70·37	70·10	67·54	67·34	67·33	68·36	69·62	67·5	64·55	..
October ..	70·70	70·20	72·18	68·37	67·82	70·21	69·42	67·2	66·78	..
November ..	70·38	71·19	66·74	69·01	67·40	67·97	69·44	67·1	64·33	..
December ..	70·87	70·57	66·37	69·32	67·25	70·25	66·04	66·5	62·00	..
Mean ..	70·46	70·21	69·44	69·34	69·19	69·13	68·95	67·3	64·42	..

TABLE IX.
RELATIVE HUMIDITY.

Month.	Axim.	Ho.	Asuansi.	Aburi.	Tarkwa.	Kumasi.	Begoro.	Ada.	Winneba.	Sekondi.
January ..	86·76	80·02	86·72	78·18	87·93	78·67	76·5	82·26	77·96	81·76
February ..	84·05	83·26	84·67	81·92	85·39	80·03	77·1	82·48	78·67	79·82
March ..	84·53	85·18	82·21	82·75	81·77	81·38	78·5	82·34	78·06	77·49
April ..	86·34	88·38	80·31	83·79	81·76	81·04	79·1	82·32	78·97	76·00
May ..	88·18	86·85	83·99	84·91	82·19	79·59	81·5	80·54	83·54	78·36
June ..	89·80	89·73	86·49	87·61	86·53	85·12	86·1	80·20	83·83	82·06
July ..	86·19	89·09	88·52	90·47	85·07	85·49	86·4	85·78	87·80	80·24
August ..	89·53	88·63	88·41	90·68	85·08	85·63	86·4	83·73	88·00	82·70
September ..	91·74	90·34	87·52	89·53	87·88	87·68	87·4	84·29	86·98	85·02
October ..	90·88	88·53	84·98	87·53	85·51	87·47	83·4	79·07	83·53	80·74
November ..	88·63	86·81	84·34	87·25	86·86	86·68	81·3	81·26	80·81	80·81
December ..	89·62	84·73	87·60	86·47	89·53	88·29	80·3	81·94	77·66	83·18
Mean ..	88·02	86·79	85·96	85·71	85·44	84·20	82·2	82·18	82·15	80·68

Month.	Saltpond.	Cape Coast.	Sunyani.	Accra.	Akuse.	Keta.	Kintampo.	Gambaga.	Tamale.	
January ..	80·46	74·03	74·80	67·2	72·45	74·93	56·76	56·08	48·24	..
February ..	75·21	78·61	69·89	72·4	69·45	71·06	65·24	54·11	49·50	..
March ..	78·50	76·43	73·40	72·2	65·91	71·06	66·80	54·66	55·07	..
April ..	79·91	77·91	74·31	72·9	69·66	71·87	68·22	61·49	57·51	..
May ..	81·49	76·99	76·71	72·3	71·84	72·59	71·86	67·39	60·00	..
June ..	85·13	81·02	80·85	76·5	75·48	71·99	77·08	78·25	67·17	..
July ..	85·38	82·88	82·60	78·8	70·43	72·34	76·60	81·52	73·58	..
August ..	82·38	86·00	84·38	77·9	73·27	74·33	76·52	85·41	71·78	..
September ..	80·96	85·66	83·10	76·6	76·18	73·41	79·60	85·33	73·24	..
October ..	80·80	80·14	81·81	70·4	74·87	70·25	74·76	75·43	67·70	..
November ..	78·43	76·70	81·14	67·4	71·39	71·45	73·10	67·12	59·50	..
December ..	78·37	79·28	79·91	72·6	75·84	71·96	67·70	62·74	51·49	..
Mean ..	80·59	79·66	79·57	73·4	72·52	72·08	71·19	69·13	61·23	..

TABLE X.

MONTHLY DISTRIBUTION OF MEAN TEMPERATURE.

Month.	Gambaga.	Tamale.	Akuse.	Ho.	Ada.	Keta.	Sekondi.	Accra.	Kumasi.	Tarkwa.
January ..	81·88	80·87	81·27	82·86	81·57	79·01	82·05	80·6	77·86	78·61
February ..	84·48	84·72	84·83	85·22	82·65	82·18	81·89	80·7	81·84	82·38
March ..	86·02	87·36	84·60	84·68	82·46	82·18	82·53	81·6	81·39	72·45
April ..	84·98	85·18	84·12	83·19	82·02	81·33	82·03	81·1	80·53	81·12
May ..	82·97	84·05	84·07	81·64	80·29	82·66	81·91	80·3	80·82	81·63
June ..	81·35	80·34	79·70	78·77	80·59	82·67	80·75	78·7	78·57	78·93
July ..	78·39	78·21	77·91	77·25	80·09	81·17	78·81	76·9	76·30	77·80
August ..	78·53	77·42	79·26	77·95	70·63	79·52	76·80	75·8	75·78	76·80
September ..	78·95	77·33	78·53	78·67	80·25	78·15	77·65	76·9	77·39	77·98
October ..	80·70	81·88	80·17	80·30	78·72	78·76	79·15	77·8	79·11	79·92
November ..	80·50	81·14	80·89	82·00	80·88	78·83	80·67	80·2	80·47	80·82
December ..	83·69	81·86	81·60	82·96	81·59	79·90	81·08	81·3	80·13	79·66
Mean ..	81·79	81·69	81·33	81·29	80·89	80·53	80·44	79·33	79·18	79·09

Month.	Kintampo.	Winneba.	Asuansi.	Aburi.	Saltpond.	Sunyani.	Axim.	Begoro.	Cape Coast.	
January ..	76·77	78·75	77·50	79·11	79·20	75·74	77·67	77·35	78·20	..
February ..	80·34	79·50	80·16	80·72	79·72	78·39	79·66	78·58	79·32	..
March ..	81·40	80·90	80·20	80·44	79·85	80·69	79·13	79·17	78·95	..
April ..	79·40	79·93	79·92	79·81	79·05	80·12	78·54	77·71	78·35	..
May ..	79·84	79·32	79·45	79·59	78·37	79·46	78·20	78·97	77·04	..
June ..	77·95	77·94	77·17	76·88	77·18	77·26	76·44	76·83	76·72	..
July ..	77·07	75·97	75·69	74·31	76·16	75·40	76·00	74·68	75·74	..
August ..	76·29	73·80	75·24	74·13	74·53	73·83	74·94	73·92	72·92	..
September ..	77·04	76·31	76·24	74·98	74·83	76·24	74·80	75·84	75·23	..
October ..	78·63	78·31	77·48	76·50	77·01	78·67	74·78	76·19	77·58	..
November ..	80·06	79·47	78·18	77·31	76·91	77·53	77·27	77·41	75·70	..
December ..	78·34	79·07	78·17	77·57	78·53	75·43	78·44	77·38	77·93	..
Mean ..	78·59	78·26	77·95	77·61	77·61	77·40	77·15	77·00	76·97	..

TABLE XI.

SOLAR MAXIMUM TEMPERATURE—MEAN MONTHLY AVERAGES.

Month.	1 Gambaga.	2 Akuse.	3 Tamale.	4 Keta.	5 Tarkwa.	6 Accra.	7 Ada.	8 Winneba.	9 Cape Coast.
January ..	153·45	139·02	143·29	140·07	136·29	141·00	144·83	141·24	138·24
February ..	153·53	147·90	147·53	142·23	145·26	142·79	147·44	137·13	141·94
March	157·99	152·83	153·19	146·66	150·56	146·50	147·22	149·41	142·79
April	156·37	153·78	151·95	148·05	151·12	147·13	151·26	151·31	144·83
May	153·36	153·06	149·36	147·81	151·63	147·73	143·53	145·75	140·35
June	148·31	148·83	145·53	145·99	142·84	146·37	141·25	140·43	139·56
July	146·62	145·16	142·13	145·42	139·97	145·11	137·84	136·41	138·14
August ..	144·91	144·46	145·21	143·63	137·67	141·02	143·83	142·63	138·06
September ..	149·69	148·20	144·41	147·73	141·94	146·73	141·46	145·42	143·44
October ..	154·17	152·52	149·37	148·00	152·62	146·37	138·84	147·71	144·11
November ..	147·79	151·35	152·15	147·98	150·56	145·11	143·45	149·25	144·10
December ..	150·79	143·66	148·14	141·80	143·02	142·92	145·77	138·63	135·19
Mean ..	150·85	148·39	147·69	145·44	145·29	144·89	143·89	143·73	140·90

Month.	10 Ho.	11 Sekondi.	12 Aburi.	13 Kintampo.	14 Sunyani.	15 Kumasi.	16 Saltpond.	17 Axim.	
January ..	134·68	129·05	140·03	130·01	130·20	131·69	129·72	114·89	..
February ..	140·45	139·03	145·73	135·14	139·51	139·80	127·57	118·41	..
March	143·90	143·67	148·45	141·04	143·48	142·25	129·60	121·23	..
April	144·49	144·47	139·60	140·21	143·39	136·97	128·60	122·17	..
May	143·65	143·54	147·13	139·44	140·98	134·97	126·92	118·16	..
June	137·89	139·51	136·22	136·67	136·70	134·65	125·77	126·73	..
July	132·25	137·30	128·21	135·61	129·51	125·25	130·12	124·95	..
August ..	134·65	134·89	129·90	136·43	127·01	121·45	126·79	125·72	..
September ..	137·11	139·50	133·30	137·46	137·01	131·82	127·27	101·24	..
October ..	144·30	144·03	142·63	143·76	140·21	138·19	105·48	110·61	..
November ..	145·15	141·00	140·17	143·33	137·20	141·78	129·76	112·89	..
December ..	141·49	136·71	139·34	136·33	132·19	134·99	130·33	116·69	..
Mean ..	140·00	139·39	139·21	137·98	136·62	134·48	126·49	117·80	..

TABLE XII.—TERRESTRIAL MINIMUM THERMOMETER READINGS.
MEAN MONTHLY AVERAGES.

Month.	1 Accra.	2 Ada.	3 Saltpond.	4 Tarkwa.	5 Kumasi.	6 Gambaga.	7 Asuansi.	8 Sekondi.	9 Cape Coast.
January ..	72·28	71·15	75·54	67·12	63·95	67·82	65·77	69·87	65·84
February ..	73·09	70·83	70·49	70·74	69·37	69·84	70·41	72·39	68·58
March	75·54	71·91	71·63	70·88	71·29	67·34	69·63	73·49	70·59
April	76·24	70·94	70·32	70·77	70·44	70·21	69·49	69·95	67·51
May	75·30	70·58	75·01	71·13	70·17	69·82	70·03	66·39	66·21
June	74·41	70·58	68·67	70·76	70·41	69·52	71·05	65·43	66·54
July	75·96	71·30	69·08	67·96	69·66	69·60	67·91	62·92	64·82
August ..	75·73	71·69	67·87	66·84	68·79	68·98	67·78	62·03	63·54
September ..	73·95	72·80	67·91	69·20	70·10	69·43	68·64	65·41	63·91
October ..	74·13	73·10	70·63	70·48	70·51	69·61	68·59	67·58	64·99
November ..	73·53	72·01	66·65	69·66	70·37	67·40	67·98	67·63	65·03
December ..	72·97	71·85	69·71	69·81	68·16	68·00	67·86	66·61	64·49
Mean ..	74·45	71·56	70·29	69·61	69·44	69·21	68·76	67·47	66·01

Month.	10 Kintampo.	11 Sunyani.	12 Axim.	13 Winneba.	14 Akuse.	15 Ho.	16 Keta.	17 Aburi.	
January ..	62·96	60·10	64·24	67·66	59·4	60·94	65·21	60·76	..
February ..	66·83	62·64	65·06	68·21	62·9	63·51	66·24	62·03	..
March	72·83	67·49	67·92	68·94	64·0	61·89	65·16	66·73	..
April	69·51	66·40	62·96	68·36	66·19	60·74	64·75	60·25	..
May	69·51	67·57	64·46	66·46	63·16	63·19	65·02	63·59	..
June	68·81	67·02	64·09	61·12	62·45	62·54	57·74	62·41	..
July	68·88	65·86	64·54	62·89	63·16	62·36	55·91	60·80	..
August ..	67·14	64·08	63·50	64·40	60·35	62·56	54·88	61·46	..
September ..	67·08	65·18	66·63	59·46	62·62	63·53	63·83	61·17	..
October ..	68·76	66·66	63·97	65·62	64·81	63·21	64·37	60·78	..
November ..	70·66	65·10	61·80	66·22	64·63	64·35	61·28	61·26	..
December ..	66·40	60·44	63·68	65·23	62·77	63·31	63·87	61·27	..
Mean ..	67·45	65·71	64·40	63·38	63·03	62·67	62·35	61·87	..

TABLE XIII.

MEAN MONTHLY DISTRIBUTION OF RAINFALL.

	1 Essuasu (2 years).	2 Atwabo (1 year).	3 Adebrem (3 years).	4 Half Assini (6 years).	5 Axim (13 years).	6 Kodeakese (2 years).	7 Agona (2 years).	8 Kintampo (13 years).	9 Adeja (1 year).	10 Birimsu (13 years).
January ..	2·00	·83	1·08	1·15	1·33	·71	·30	·24	·84	1·44
February ..	1·12	·68	2·23	2·77	1·99	5·29	2·62	1·75	1·76	2·77
March ..	8·34	3·22	4·11	7·96	5·10	10·13	4·13	4·43	6·58	5·71
April ..	5·43	9·83	9·87	6·82	4·45	16·51	8·10	6·35	10·91	6·46
May ..	12·41	10·59	9·09	11·19	14·14	12·34	6·67	8·42	9·56	7·92
June ..	16·07	20·02	17·58	22·31	17·53	22·55	14·79	10·87	4·51	9·79
July ..	1·92	3·13	8·13	3·65	8·68	11·38	5·37	7·49	4·06	7·03
August ..	·72	·05	1·88	·55	1·95	2·53	3·68	4·21	1·32	4·68
September ..	13·41	2·80	3·87	2·80	3·09	32·10	10·43	12·70	12·23	8·11
October ..	13·32	11·26	5·36	6·89	7·03	23·35	9·44	9·29	15·05	8·36
November ..	10·83	6·32	4·70	6·47	7·72	5·68	5·02	4·02	2·45	5·11
December ..	2·27	10·29	1·56	4·61	3·38	4·80	1·59	·37	1·38	3·07
Mean total	88·00	79·02	77·49	77·18	76·29	73·53	72·12	70·75	70·65	70·45
Highest	—	—	79·47	88·77	109·65	85·83	—	100·58	—	82·70
Lowest	73·38	—	50·43	61·63	47·64	—	67·15	48·87	—	54·14

TABLE XIII.—*continued.*

MEAN MONTHLY DISTRIBUTION OF RAINFALL (*continued*).

	11 Bunsu (8 years).	12 Tarkwa (24 years).	13 Asromaso. (1 year).	14 Begoro (6 years).	15 Mpraeso (10 years).	16 Hemang (10 years).	17 Mpirim (2 years).	18 Abompaso (6 years).	19 Effiduase (1 year).	20 Anyinam (21 years).
January ..	1·42	1·84	—	1·53	·86	·83	1·04	·69	·05	1·10
February ..	2·55	3·21	·75	3·73	1·96	3·33	6·74	1·89	1·51	2·52
March ..	4·33	6·12	3·44	6·58	4·67	7·36	7·45	5·62	3·60	6·12
April ..	5·54	6·99	5·87	10·63	6·02	7·07	20·99	6·39	6·60	6·15
May ..	8·11	8·70	5·52	8·06	7·91	8·66	22·27	7·92	6·29	8·29
June ..	9·87	11·16	7·29	8·54	9·25	8·50	22·42	10·92	7·98	9.67
July ..	8·83	5·60	4·18	3·23	7·31	5·16	8·53	6·13	6·00	7·20
August ..	4·96	2·01	1·95	2·61	4·25	2·89	2·73	2·33	1·17	3·53
September ..	8·42	4·43	8·22	7·35	9·11	5·45	18·73	7·16	16·31	7·72
October ..	9·34	8·26	15·47	10·66	9·01	8·31	14·85	9·30	13·89	8·42
November ..	3·38	6·69	2·31	3·78	4·74	6·68	5·26	8·80	·67	3·47
December ..	3·14	3·39	·36	1·46	2·43	2·86	2·95	2·80	2·09	1·60
Mean total	68·86	68·42	68·36	68·17	67·78	67·08	66·98	66·95	66·16	65·80
Highest	—	95·03	—	72·86	85·26	85·86	67·14	67·39	—	95·07
Lowest	—	48·22	—	50·43	57·55	47·04	—	65·18	—	46·27

TABLE XIII.—(*continued*).

MEAN MONTHLY DISTRIBUTION OF RAINFALL—(*continued*).

	21 Juaso (12 years).	22 Nkwatia. (10 years).	23 Kibi (15 years).	24 Siwum (6 years). (Dadiasu)	25 Nkawkaw (2 years).	26 Bekwai (14 years).	27 Tafo (2 years).	28 Obuasi (4 years).	29 Asa-mankese (5 years).	30 Ejisu (2 years).
January ..	·75	·70	1·13	·65	·50	·78	·89	2·16	1·45	1·23
February ..	1·67	2·32	2·95	1·96	1·12	2·79	1·56	2·29	2·08	5·58
March ..	6·19	4·60	6·61	4·61	4·82	5·50	4·58	4·55	6·90	9·35
April ..	6·45	6·29	7·25	7·02	6·42	7·79	5·10	5·58	7·24	18·48
May ..	7·46	7·60	6·87	9·42	5·18	8·64	7·38	7·15	7·37	13·71
June ..	9·97	9·60	9·75	10·72	8·48	9·98	13·36	9·86	9·40	16·90
July ..	5·91	6·49	4·66	7·85	7·78	5·18	4·42	7·50	4·79	9·13
August ..	2·59	4·11	2·71	1·92	2·48	2·34	·99	4·19	2·25	2·09
September ..	8·19	9·02	5·95	5·98	10·95	5·79	6·99	6·72	4·19	19·13
October ..	9·52	8·52	7·93	8·30	11·42	7·97	9·66	5·35	6·21	19·85
November ..	4·92	4·35	6·10	4·88	3·67	5·38	5·67	5·75	5·44	4·46
December ..	1·79	1·40	2·37	1·46	1·77	1·36	2·00	·93	4·34	1·34
Mean total	65·48	65·00	64·96	64·74	64·59	63·51	62·11	62·03	61·73	60·68
Highest	75·19	79·21	79·90	73·62	—	104·90	—	76·75	77·47	64·45
Lowest	53·42	60·73	45·77	57·67	—	46·21	—	36·58	51·43	—

TABLE XIII.—*continued.*

MEAN MONTHLY DISTRIBUTION OF RAINFALL (*continued*).

	31 Oda (13 years).	32 Mansu (14 years).	33 Ejura (12 years).	34 Kumasi (21 years).	35 Mpenasa (3 years).	36 Tikrom (2 years).	37 Anyinasu (7 years).	38 Wiawso (12 years).	39 Ho (6 years).	40 Mampong (Ashanti) (2 years).
January ..	·84	2·34	·56	·53	1·72	·48	·23	1·05	·82	—
February ..	1·95	2·18	2·03	2·20	4·02	1·31	3·27	1·73	3·67	2·75
March ..	5·46	4·24	4·46	5·26	3·62	9·09	5·69	5·58	4·44	5·35
April ..	6·87	5·83	5·36	6·28	3·38	14·58	6·90	5·78	6·97	15·32
May ..	7·02	8·49	7·25	6·58	8·78	12·64	7·88	6·90	6·53	24·19
June ..	8·32	11·6	7·56	8·72	19·41	17·95	8·63	9·96	7·14	17·08
July ..	4·03	4·33	4·23	5·40	4·95	10·64	3·79	5·28	3·81	4·70
August ..	2·41	1·64	2·69	3·09	·83	2·04	1·58	1·95	2·37	1·25
September ..	6·14	4·61	9·21	7·07	3·23	15·84	4·80	5·69	6·77	19·19
October ..	7·54	6·24	8·20	8·10	3·62	22·65	6·77	6·69	6·92	14·60
November ..	7·15	5·24	4·52	4·03	2·58	4·99	4·79	4·54	5·08	4·44
December ..	2·57	3·61	1·07	1·24	1·94	2·66	2·69	1·84	1·91	2·00
Mean total	60·19	59·92	59·23	58·50	58·07	57·42	57·02	56·99	56·26	56·23
Highest	83·75	83·70	80·75	70·40	60·27	59·37	70·03	70·44	52·16	59·96
Lowest	43·61	54·46	47·45	40·07	58·96	—	41·95	40·14	49·77	—

TABLE XIII.—*continued.*

MEAN MONTHLY DISTRIBUTION OF RAINFALL—(*continued.*).

	41 Dunkwa (13 years).	42 Wenchi (6 years).	43 Yendi (6 years).	44 Sunyani (13 years).	45 Kpetsu (4 years).	46 Nsawam (2 years.)	47 Peki (13 years).	48 Salaga (13 years).	49 Koforidua (6 years).	50 Angu (2 years).	51 Goaso (4 years).
January ..	·68	·16	·79	·54	1·07	1·52	·56	·25	·31	·99	·36
February ..	1·71	2·29	·30	1·90	3·11	1·52	1·92	·56	2·83	·88	1·47
March ..	4·90	2·78	1·72	5·00	6·52	4·18	3·78	2·42	3·42	4·55	2·57
April ..	7·16	7·81	6·03	6·42	5·51	3·02	5·78	4·84	6·25	2·37	8·55
May ..	7·15	6·01	5·96	6·13	5·87	8·30	5·59	5·45	5·33	9·13	6·52
June ..	9·87	7·98	5·90	6·75	7·39	10·51	8·52	7·41	10·68	13·72	6·59
July ..	5·14	3·21	6·13	5·26	2·39	2·24	4·99	5·94	3·32	1·37	3·61
August ..	2·31	2·09	6·39	2·25	2·15	·15	3·34	6·56	·83	·36	1·30
September ..	5·05	8·62	14·73	7·61	4·46	5·88	6·04	10·21	5·19	5·00	5·81
October ..	6·26	9·58	5·19	7·71	7·61	6·69	5·95	6·28	6·94	6·62	8·86
November ..	4·27	3·79	·85	3·61	4·60	3·38	4·14	1·64	3·18	2·79	4·63
December ..	1·70	·38	—	·42	1·70	4·80	1·47	·09	3·01	3·47	·62
Mean total	56·20	54·88	53·98	53·61	52·38	52·20	52·09	51·57	51·30	51·27	50·90
Highest	77·91	60·95	67·12	69·47	51·95	—	68·46	64·52	53·97	—	59·50
Lowest	45·55	58·25	46·12	41·30	40·07	49·01	36·33	37·79	51·78	49·58	44·94

TABLE XIII.—(*continued.*)

MEAN MONTHLY DISTRIBUTION OF RAINFALL (*continued.*).

	52 Labolabo (8 years).	53 Butre (Seysie) (7 years).	54 Asuansi (19 years).	55 Kete- Kratchi (9 years).	56 Aburi (37 years).	57 Wa (11 years).	58 Navrongo (2 years).	59 Ajua (8 years).	60 Gambaga (3 years).	61 Odumasi (3 years).	62 Zuarungu (10 years).
January ..	1·17	1·52	1·43	·67	1·06	·43	·00	·76	—	·03	·07
February	2·24	2·06	2·63	1·48	2·19	·44	·00	1·48	·03	·83	·07
March ..	5·09	3·04	3·93	2·64	3·89	1·35	·82	2·37	·14	3·35	·53
April ..	5·88	3·42	5·41	4·11	5·26	3·48	2·64	3·05	3·72	4·86	3·63
May ..	5·77	9·39	7·01	5·31	6·13	6·25	4·68	7·50	6·47	3·41	3·51
June ..	6·97	14·62	8·97	8·06	7·54	5·37	7·17	13·11	5·29	5·48	6·54
July ..	5·18	3·98	4·05	6·59	3·68	5·73	9·48	4·05	6·17	3·27	5·48
August ..	3·23	·72	2·45	3·47	2·12	8·00	9·47	·83	7·97	1·56	10·41
September ..	6·05	2·90	3·31	8·31	3·57	9·82	10·25	2·38	10·62	3·11	10·04
October ..	5·11	4·57	4·67	5·78	5·52	3·20	1·05	5·39	2·97	4·87	2·33
November ..	2·64	1·86	3·53	2·15	4·58	1·06	·00	2·00	1·32	4·66	·72
December ..	1·48	2·28	2·68	·49	2·25	·50	·00	1·96	—	1·36	—
Total mean	50·81	50·36	50·07	49·03	47·79	45·62	45·56	44·91	44·63	44·14	43·37
Highest	50·10	58·96	74·17	60·41	73·16	50·71	—	49·03	59·34	49·77	51·62
Lowest	48·92	58·30	35·62	43·61	32·09	29·08	—	36·81	13·07	43·43	37·93

TABLE XIII—*continued.*

MEAN MONTHLY DISTRIBUTION OF RAINFALL—*continued.*

	63 Tamale (18 years).	64 Inchaban (1 year).	65 Akuse (13 years).	66 Sekondi (24 years).	67 Cape Coast (6 years).	68 Abra (6 years).	69 Ada (7 years).	70 Saltpond (13 years).	71 Winneba (7 years).	72 Accra (41 years).	73 Keta (22 years).
January ..	·04	·63	·64	1·23	·72	·51	·14	·45	·58	·61	·55
February ..	·28	·89	1·55	1·08	·81	1·37	·43	·46	·56	1·16	1·09
March ..	2·42	3·98	3·61	2·18	2·53	2·74	2·25	2·71	2·09	1·89	1·53
April ..	3·08	1·78	5·49	3·84	4·01	2·25	3·67	3·13	3·09	3·68	3·11
May ..	4·58	5·36	5·53	8·51	7·21	5·96	7·36	6·11	5·27	5·21	4·70
June ..	5·94	18·40	6·45	9·22	9·11	9·19	7·81	8·38	6·76	6·98	6·57
July ..	5·28	1·70	3·00	3·82	5·85	1·51	3·10	2·37	2·45	1·64	2·03
August	7·97	·45	1·38	1·35	1·51	·18	·82	·69	·57	·64	·75
September ..	8·76	3·25	3·94	2·08	1·46	1·68	·99	1·47	2·23	1·17	1·25
October ..	2·99	2·22	4·71	2·74	2·69	3·61	3·46	2·33	3·83	2·27	2·95
November ..	·81	2·01	3·26	2·72	3·03	1·96	1·71	2·07	1·45	1·34	1·59
December ..	·12	·71	1·59	1·39	1·16	1·61	·31	1·12	·59	·85	·54
Mean total	42·22	41·38	41·09	40·18	40·10	32·56	32·05	31·27	27·91	27·43	26·66
Highest	61·77	—	58·98	57·76	56·25	34·18	45·97	43·80	44·27	44·20	51·44
Lowest	32·36	—	35·14	32·98	30·19	27·28	12·58	24·38	14·60	10·84	13·88

TABLE XIII.—(*continued*).

MEAN MONTHLY DISTRIBUTION OF RAINFALL (*continued*).

			Incomplete Records.				Annual Totals only.			
	74 Labadi (5 years).	75 Achimota (3 years).	76 Kpeve (10 mths.).	77 Abetifi (10 mths.)	78 Akropong (10 mths.)	79 Bole (10 mths.)	80 Akwan-tambra.	81 Jema	82 Sukusuku	83 Senchi
January ..	·49	·58	—	·85	—	—	—	—	—	—
February ..	1·61	1·90	—	·36	—	—	—	—	—	—
March ..	3·31	2·50	4·31	3·80	2·05	·03	—	—	—	—
April ..	2·21	2·05	4·44	3·29	2·73	9·62	—	—	—	—
May ..	4·14	3·13	5·33	6·88	4·09	6·87	—	—	—	—
June ..	6·55	5·58	5·91	3·95	4·96	10·33	—	—	—	—
July ..	·67	1·15	5·10	2·48	1·03	7·82	—	—	—	—
August ..	·34	·15	·52	·21	—	4·20	—	—	—	—
September ..	1·24	1·74	9·99	9·37	4·24	9·18	—	—	—	—
October ..	2·50	1·55	9·56	11·60	5·77	5·97	—	—	—	—
November ..	·42	2·10	2·11	—	—	·60	—	—	—	—
December ..	1·85	2·12	2·53	—	4·14	—	—	—	—	—
Mean total	25·33	24·54	49·80	42·99	29·01	54·62	60·00	70·00	70·00	40·00
Highest ..	36·87	24·09	—	—	—	—	—	—	—	—
Lowest .	10·78	21·00	—	—	—	—	—	—	—	—

TABLE XIII—*continued.*

MEAN MONTHLY DISTRIBUTION OF RAINFALL—*continued.*

German Records (Togoland).

	Nyangbo.	Tafie.	Wuropong.	Gjasekan.	Kpando.	Kpeme.
January ..	1·32	1·73	0·0	·55	·80	·52
February ..	1·71	1·89	2·76	·61	2·32	1·16
March ..	4·98	4·69	5·33	2·60	4·94	1·91
April	5·02	5·40	3·79	6·00	5·01	3·77
May	6·40	6·34	4·71	6·23	5·33	7·01
June	10·05	8·69	3·18	6·94	6·52	9·76
July	5·96	6·84	11·91	7·25	6·10	3·10
August ..	4·39	3·98	10·49	5·11	3·48	·28
September ..	6·85	6·19	5·66	9·76	6·93	1·31
October ..	5·61	5·45	5·21	6·80	6·25	2·54
November ..	2·81	3·01	1·42	1·75	2·72	1·32
December ..	1·49	1·24	0·0	·75	1·45	·32
Total ..	56·60	55·45	54·46	54·35	53·85	32·00
Highest ..	72·14	77·32	—	64·77	62·62	44·74
Lowest ..	39·66	42·46	54·02	41·91	40·02	22·97